Vol. 57 • No. 9

September 2014

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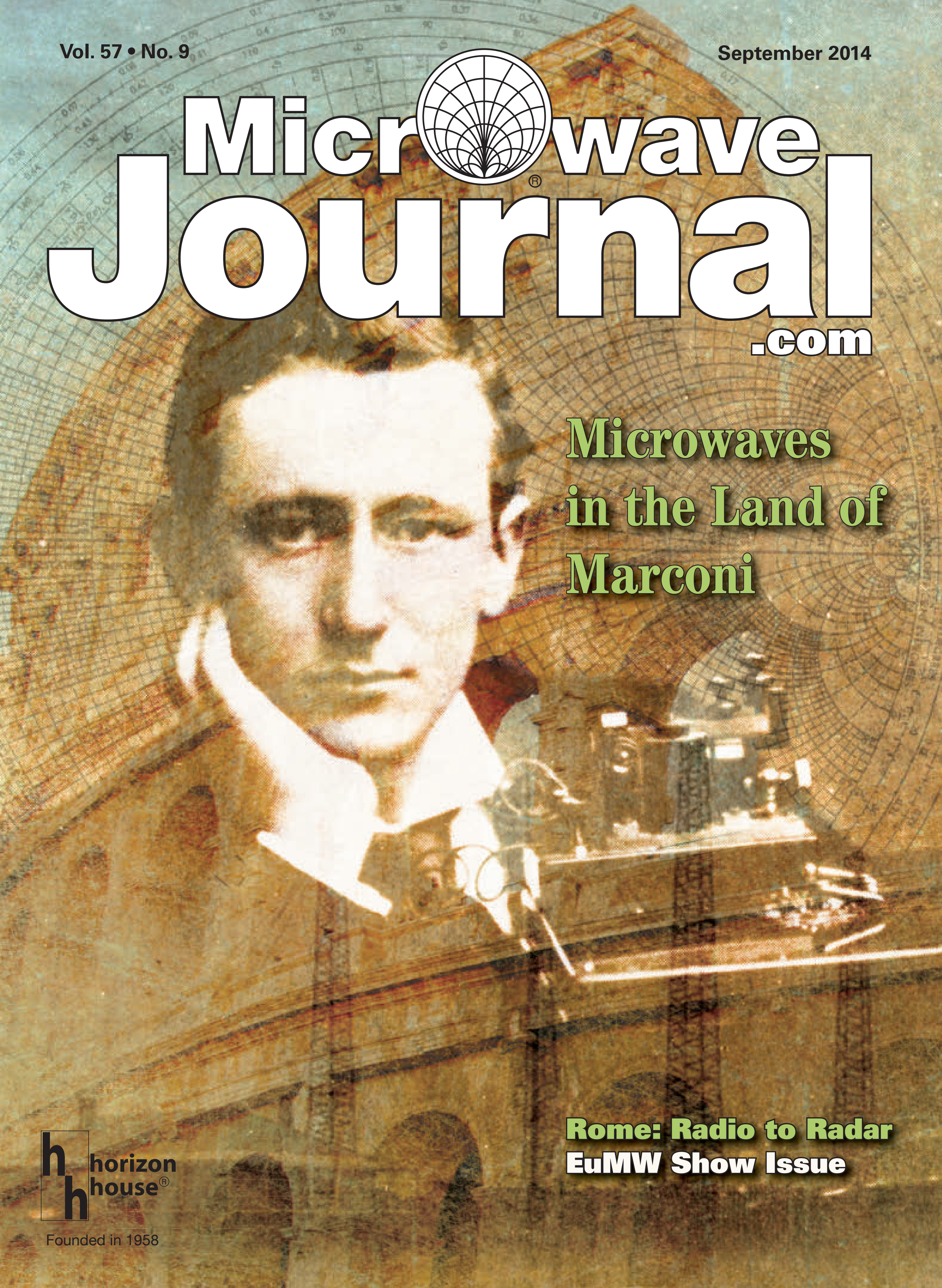

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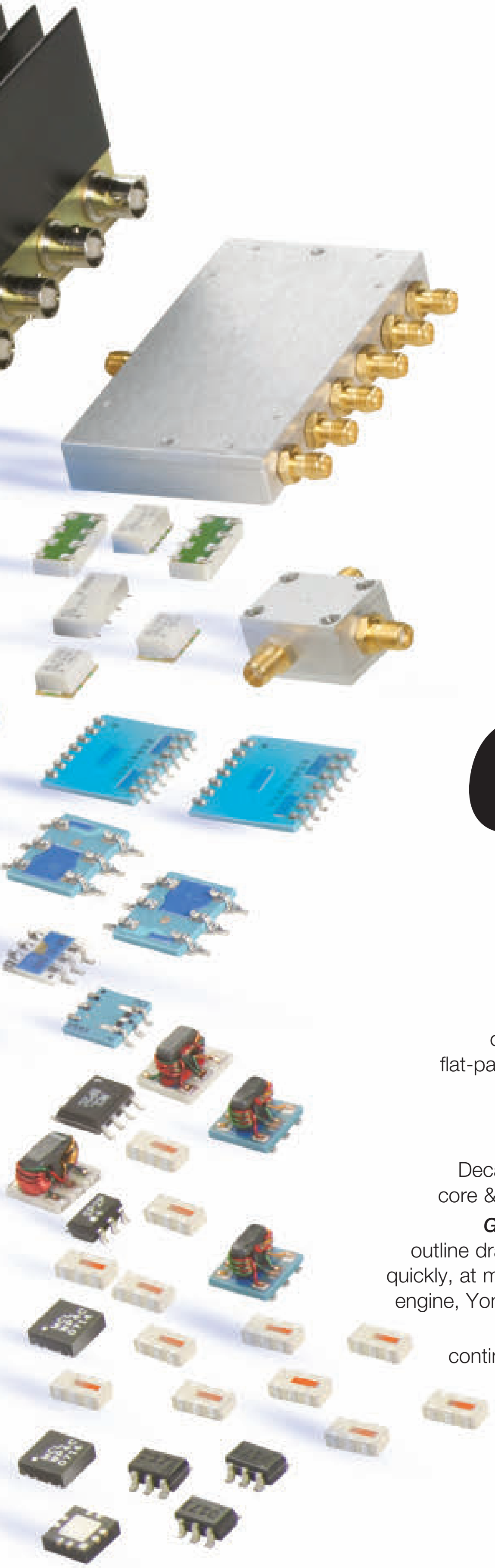

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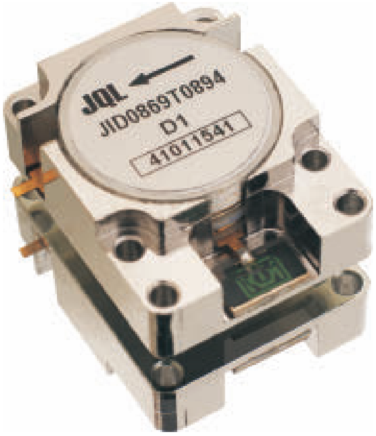

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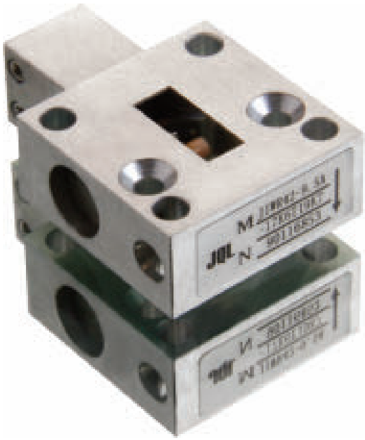

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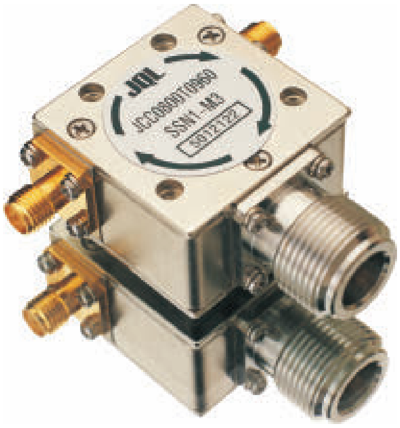

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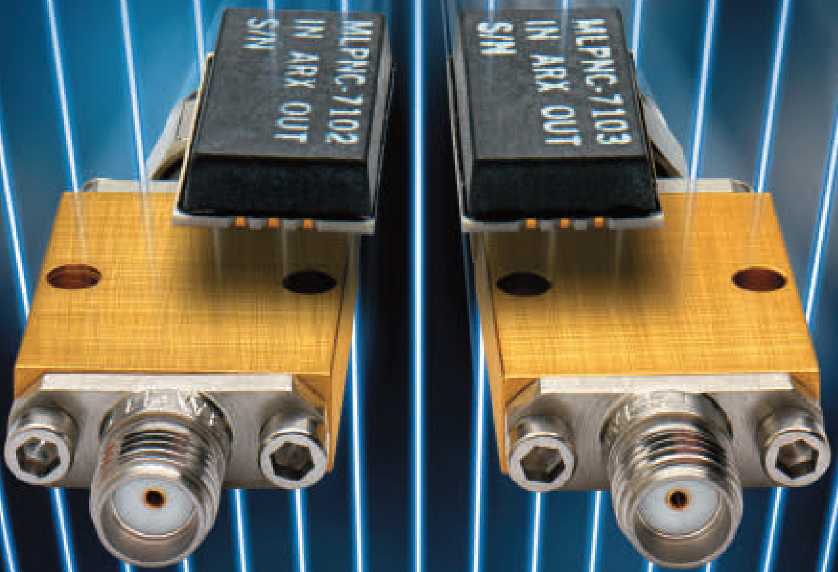

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MLPNC-7103-SMT680	21 @ 800 MHz	23 @ 1300 MHz	> -5 @ 6 GHz	> -15 @ 18 GHz	> -20 @ 30 GHz

* Contact the factory for additional information or for products not covered in the table.

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Executive Editorial Office:
685 Canton Street, Norwood, MA 02062
Tel: (781) 769-9750
FAX: (781) 769-5037
e-mail: mwj@mwjournal.com

European Editorial Office:
16 Sussex Street, London SW1V 4RW, England
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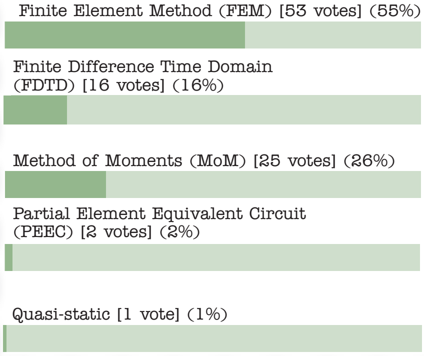

Executive Interview

Dr. Ignacio Montiel-Sanchez, project officer of RF sensors technologies at the European Defence Agency explains the agency's efforts to improve the EU's defence capabilities through cooperative projects and programmes.

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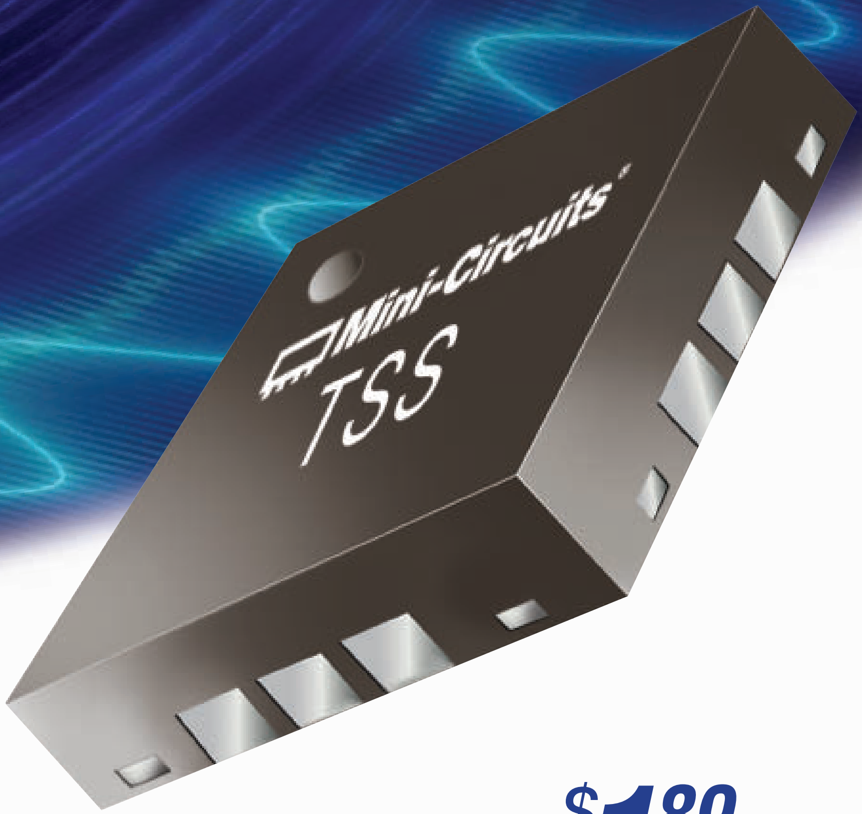
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5 EuMW 2014 EUROPEAN MICROWAVE WEEK ROME, ITALY 5-10 OCTOBER 2014 www.eumweek.com	6 MILCOM 2014 Affordable Mission Success: Meeting the Challenge Baltimore, MD	7 **Webinar: VCO Fundamentals** Sponsored by Mini-Circuits	8 **Defence, Security and Space Forum at EuMW** Rome, Italy	9 **Webinar: Lightning and EMP Protection Buildings** Sponsored by CST	10	11
12 AMTA 2014 TUCSON Tucson, AZ	13	14	15	16 **Webinar: Simulation of Accelerator Components** Sponsored by CST	17	18
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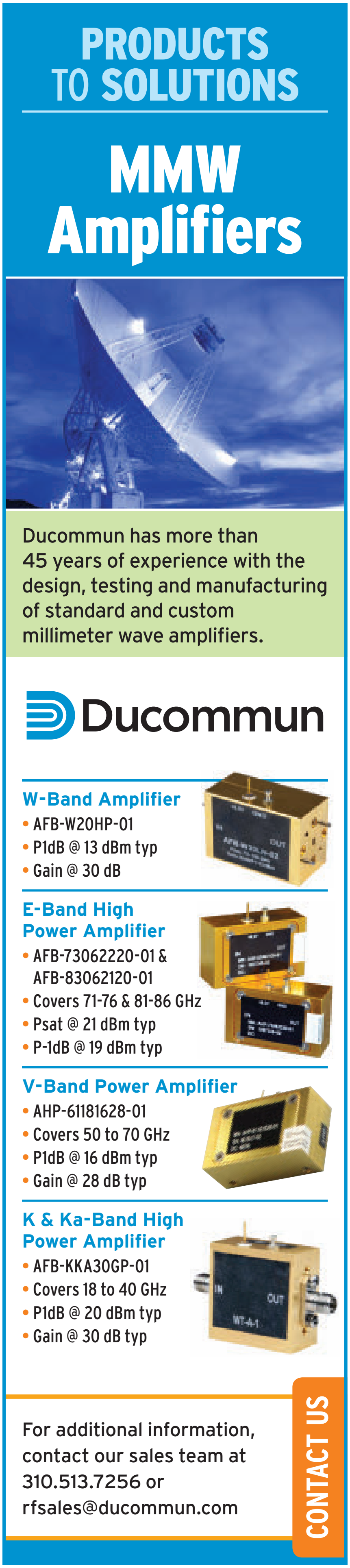

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Call for Papers

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October 31, 2014

IMS 2015
December 8, 2014

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SEPTEMBER

ION GNSS+ 2014
September 8–12, 2014 • Tampa, Fla.
www.ion.org

Super Mobility Week 2014
September 9–11, 2014 • Las Vegas, Nev.
www.supermobilityweek.com

4G World 2014
September 9–11, 2014 • Las Vegas, Nev.
www.4gworld.com

IRMMW-THz 2014
39th International Conference on Infrared, Millimeter and Terahertz Waves
September 14–19, 2014 • Tucson, Ariz.
www.irmmw-thz2014.org

AUTOTEST 2014
September 15–18, 2014 • St. Louis, Mo.
www.ieee-autotest.com

OCTOBER

EuMW 2014
European Microwave Week
October 5–10, 2014 • Rome, Italy
www.eumweek.com

MILCOM 2014
October 6–8, 2014 • Baltimore, Md.
www.milcom.org

The 2014 Defence, Security and Space Forum at European Microwave Week
October 8, 2014 • Rome, Italy
www.eumweek.com

AMTA 2014
36th Antenna Measurement Techniques Association Meeting & Symposium
October 12–17, 2014 • Tucson, Ariz.
www.amta2014.org

ITC/USA 2014
October 20–23, 2014 • San Diego, Calif.
www.telemetry.org

MWP/APMP 2014
International Topical Meeting on Microwave Photonics (MWP)
9th Asia-Pacific Microwave Photonics Conference (APMP)
October 20–23, 2014 • Sapporo, Japan
www.mwp2014.com

IME/China 2014
9th International Conference & Exhibition on Microwave and Antenna
October 29–31, 2014 • Shanghai, China
www.imwexpo.com

NOVEMBER

APMC 2014
Asia-Pacific Microwave Conference
November 4–7, 2014 • Sendai, Japan
www.apmc2014.org

electronica 2014
November 11–14, 2014 • Munchen, Germany
www.electronica.de

DECEMBER

Precise Time and Time Interval Systems and Applications
December 1–4, 2014 • Boston, Mass.
www.ion.org/ptti

ARFTG 84th Microwave Measurement Conference
December 2–5, 2014 •Boulder, Colo.
www.arftg.org

JANUARY 2015

Radio and Wireless Week
January 25–28, 2015 • San Diego, Calif.
www.radiowirelessweek.org

MARCH

Mobile World Congress
March 2–5, 2015 • Barcelona, Spain
www.mobileworldcongress.com

Satellite 2015
March 16–19, 2015 • Washington, DC
www.satshow.com

APRIL

EDI CON 2015
Electronic Design Innovation Conference
April 14–16, 2015 • Beijing, China
www.ediconchina.com

MAY

IMS 2015
May 17–22, 2015 • Phoenix, Ariz.
www.ims2015.org

The Mission Remains the Same...

Carl Sheffres, Microwave Journal *Publisher*

Last month, David Vye bid farewell to our readers in his final "Editor's Note." After seven years with *Microwave Journal* he has returned to industry, to the good fortune of his new employer. David accomplished much during his tenure as editor, providing editorial leadership and driving numerous new initiatives that enhanced our coverage and expanded our brand. In particular, his efforts in launching MWJ China and EDI CON China were critical to the success of those endeavors.

I expect that our readers will miss David's informative and witty narratives, our clients will miss his collaboration and marketing savvy and we at *Microwave Journal* will miss his camaraderie and contributions. David will remain associated with MWJ as a consulting editor, so we'll have the benefit of his continued input. We wish him well.

I'm pleased to announce that Pat Hindle will take over the role of editor of *Microwave Journal* moving forward. Pat has served as technical editor for more than six years, helping lead the editorial direction of our publication. He has also been instrumental in building the digital and social media components of MWJ that are so important in today's media environment. Pat's experience, industry knowledge and editorial vision will carry on the MWJ mission of delivering the most useful, timely and practical technical content for the RF/microwave engineering community. We're in good hands with Pat at the helm.

I'm also pleased to announce the newest addition to the *Microwave Journal* editorial team. His name is Gary Lerude, and like his predecessors, Gary brings a wealth of industry experience and contributions to his new role as technical editor. Gary has 36 years of experience as a working design engineer in the RF/microwave industry, numerous accomplishments in product development/management and vast knowledge of strategic marketing and business development in both the commercial and aerospace/defense sectors. As an accomplished technologist and writer, Gary is highly qualified for his new role and I know that he's excited to get started. You'll be hearing more about and from Gary in the very near future.

This issue of MWJ is our annual European Microwave Week show issue. International editor Richard Mumford provides his Special Report on "Microwaves in Europe: Vision 2020" along with a preview of what attendees can expect to find at the conference and the exhibition. The conference includes the "Defence, Security and Space Forum"; a one day event addressing the application of RF integrated systems to defence & security infrastructure. The day includes an industry panel session featuring industry experts, the EuRAD opening session, a market analysis perspective from Strategy Analytics and concludes with a networking cocktail reception. If you plan to travel to Rome in early October for EuMW (and I hope that you do), I encourage you to register for the Forum at www.eumweek.com. The exhibition is sold out and features many of the leading companies in the industry. You will find the list of exhibitors and some of the products to be displayed in the back pages of this issue. This month's cover feature entitled "European RF Defence Sensors Systems Challenges and Innovation" is contributed by Ignacio Montiel-Sanchez. A mouthful for sure, but well worth the read.

Pat, Gary, Richard and I will be attending EuMW along with the rest of our European team. We'll be learning about the latest technologies and products from the leading innovators and companies in the industry. Some things never change. ■

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COVER FEATURE
INVITED PAPER

European RF Defence Sensors Systems Challenges and Innovation

Ignacio Montiel-Sanchez
European Defence Agency (EDA), Belgium

RF sensors providing functionalities such as detection, tracking and identification of targets and RF signals are based on a multifaceted set of performance technology enablers hardly imagined a few years ago. In this article, the challenges that the European RF Sensor Research and Technology (R&T) community is facing are discussed with a systems-level perspective. The aim is to produce RF sensor systems that comply with current performance demands at an adequate cost, taking into account evolving scenarios and fluctuating requirements.

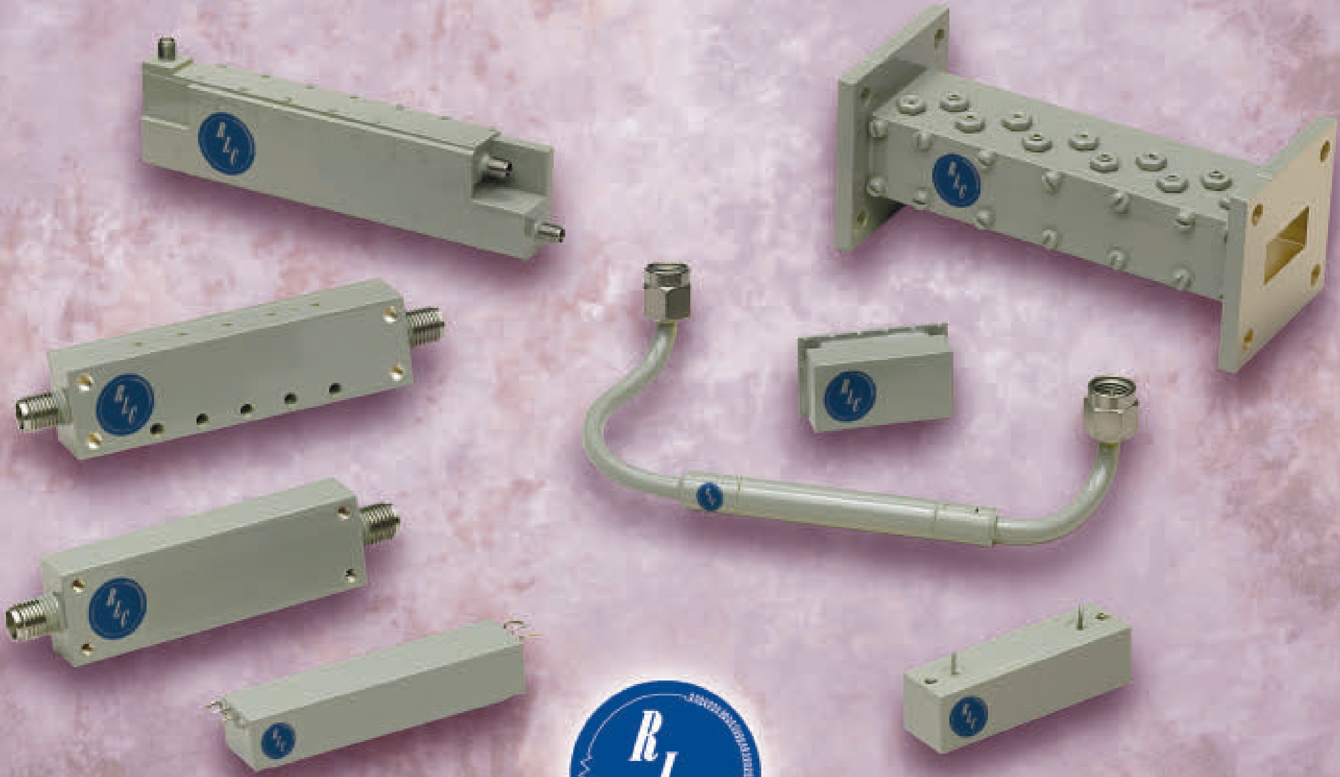
The way these challenges can be faced optimally in Europe is through the implementation of collaboration programs in defence R&T like those under the framework of the European Defence Agency (EDA). Research trends related to these kinds of sensors and some characteristics of related program schemes are analyzed. The interest in standard architectures based on building blocks (BB) developed through system engineering approaches is highlighted in this article. The involvement of scientists and engineers must adequately be taken into account in order to optimize results and processes within the European supply chain.

FROM HERTZ AND TESLA TO COGNITIVE, ADAPTIVE AND SELF-LEARNING RF SENSORS

Many years ago, Heinrich Rudolf Hertz (1857–1894) failed to give value to his own experiments and discoveries, stating that they were of no use even when he had proven the existence of Electromagnetic Fields (EMF) previously theorized by James Clerk Maxwell. It is evident that he could not imagine the huge number of possibilities he had created for the future and how significant his experiments were. Unfortunately, Hertz died very young, but other geniuses like Nicola Tesla (1856–1943) were able to capitalize on several of the possibilities in very innovative ways.

The world has evolved much from the times of Hertz and Tesla. The romantic figure of the wise researcher stimulating vocations of engineers and physicists is progressively disappearing. Interest in technical careers seems to be declining in favor of more humanistic and chrematistic pursuits, even if the current delight provided by the social media comes from defence research.[1] The number of engineers working on defence technologies in Europe is steadily decreasing and the demographic is aging. Their skills and knowledge will disappear if new R&T collaborative projects with clear procurement paths are not established soon.

Understanding the importance of the RF sensors market is critical. In 2012 the revenue corresponding to global defence exports for radar technology exceeded $7 billion.[2] An analysis



by Visiongain market research indicates that the military radar systems market was valued $8.57 billion in 2013 and an estimation of the global Electronic Warfare (EW) market is $12.15 billion for 2014, with the expectation of reaching $15.59 billion by 2020.[3]

From the equipment perspective, the explosion in performance provided by devices like ubiquitous FPGAs, GPUs "spawned by the $80 billion video gaming industry[4]" and ASICs makes it possible to incorporate increasingly closer to human behaviors with progressively decreasing size, weight, power and cost (SWaP-C). The ability to adapt to the environment and self-learn will provide a strong tool to the systems of the next generation coping with the challenges imposed by the threat evolution.[5]

THE DEFENCE ENVIRONMENT AND ITS CHALLENGES IN 2014

The concept of defence has certainly evolved, but military capabilities must adapt to current scenarios, many times mixing with civil or more precisely, security capabilities. For the last 50 years military concepts have been based on conventional warfare, relying on deterrence as the principal way of avoiding wars. Nowadays the focus has shifted toward asymmetric/unconventional warfare and cyber attacks, seriously affecting other domains and redefining electronic warfare (EW) approaches. This evolving scenario has led to the need for flexibility and readiness. Advances in technology allow for very complex systems that can flexibly and adaptively respond to new threats and deployment scenarios. This imposes challenges in the validation and verification of new assets as a system's performance may be downgraded or lose generality when forced to adapt to a new environment.

The EDA RF Sensors community is seeking systems that will provide situational awareness through more persistent surveillance and is focusing its efforts on improving sensitivity to detect increasingly challenging targets in complex environments with high levels of RF interference, spectrum regulation constraints and dense clutter. Some examples are listed in ***Table 1***.

TABLE I

CHALLENGING TARGETS

Environments	*Targets*
Maritime	Small boats made of wood or rubber Sea skimming missiles Stealth ships and Unmanned Maritime Systems (UMS) Mobile and fleeting targets
Urban	Vehicles and personnel Mines and Improvised Explosive Devices (IED) Rockets and mortars Behind the wall targets Unmanned Ground Systems (UGS)
Wide Ground Areas	Ground targets hidden by camouflage, concealment and deception Targets in clutter of mountainous terrains and under foliage
Air	Tactical Ballistic, Anti-Ship and Cruise Missiles Low speed, low flying aircraft High speed reconnaissance aircraft, satellites, supersonic missiles Low Radar Cross Section - stealth: Fighters, bombers, missiles, Unmanned Air Systems (UAS)

Beyond detection, targets must also be tracked and identified to avoid fratricide in case of engagement. This normally requires complex algorithms to perform multi-tracking, including sensor fusion and the population of target databases scrutinized in near real-time to provide the correct identification of the target type and its potential for hostility.

There is an increasing need for advanced technology and information superiority to support future military operations in a fiscal atmosphere of reduced R&D expenditure. For the 26 EDA pMS in 2012 this reduc-

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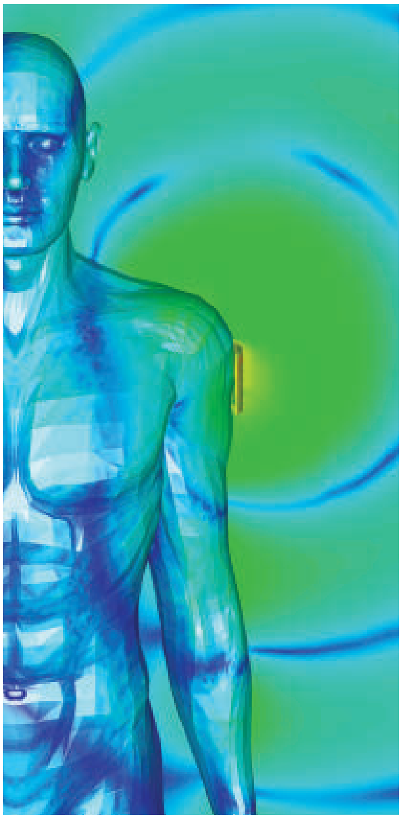

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CST SUCCESS STORY

PULSE ELECTRONICS IMPROVES ANTENNA EVALUATION AND REDUCES PRODUCT DESIGN LEAD TIME WITH CST MICROWAVE STUDIO

Heikki Korva, Team Manager, RF, Pulse Electronics Wireless Division

Figure 1 LTE antenna audio-module, from simulation to mass production.

Pulse Electronics Mobile Division produces compact antennas for mobile communications and networking. Mobile antennas need to function in complex and mechanically limited environments, and so most antennas used today are specially designed and customer-specific.

About Pulse Electronics Wireless Division

Pulse Electronics boosts appealing mobile devices by providing intelligent antenna design and manufacturing solutions for handsets, tablets, laptops, small cell base stations and PMR.

Our aim is to optimize antenna designs for complex multi-radio environments under all circumstances. The carefully developed Pulse solutions truly delight end users.

Pulse has delivered close to 2 billion antennas to the leading manufacturers of mobile devices. Pulse Wireless Division is headquartered in San Diego, USA, and has sites in Finland, China, South Korea, and Taiwan.

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The antenna is one of the first electromechanical components considered in a new product concept design. In the past, most of the R&D work was done in the laboratory, with the engineers constructing and testing different antenna designs for customers' products. While this is still a good approach for single antenna systems, the introduction of LTE diversity schemes and other radio systems such as Wi-Fi and GPS to current smartphones make reliable prototype evaluation very challenging.

Antenna prototypes typically include the device ground, PCBs, batteries, covers and any other large parts. Obviously, early prototypes seldom include any active transceivers, and so each antenna must be driven from an external coaxial cable. A typical LTE smartphone, with its main and diversity antennas, GPS and GLONASS systems and 2.4 GHz and 5 GHz WLAN capabilities, can need 7 or 8 cables to measure all the components at once. These cables would occupy too much of the volume of the prototypes, and severely distort the evaluation results. With electromagnetic simulation, the performance of a complex device can be calculated without worrying about these cable effects.

An example of an antenna product designed using only CST MICROWAVE STUDIO® (CST MWS) is shown in **Figure 1**.

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TABLE II

RF SENSORS TAXONOMY

	Antenna Scanning	*Configurations TX-RX*
Active vs. Passive Fixed vs. Adaptive-Cognitive Analog vs. Digital Single vs. Multi-Function Cooperative vs. Non-Cooperative	Mechanically Steered Passive Steered Array Active Electronic Steered Array RF/Photonic/Digital Beamforming	Monostatic Bistatic Multistatic MIMO

Domains	*Waveforms*	*Capabilities/Functionalities*
Land Maritime Air Space Cyber	Continuous Wave FMCW/Interrupted-FMCW Pulsed Stepped Freq-Synthetic Pulsed Pulse Compressed-Chirp Frequency Agile Phase Coded (Barker-Polyphase) Ultrawideband OFDM	Detection/Tracking/Identification/Targeting Air Traffic Control Fire Control Ground Moving Target Indication Navigation/Guidance/Detect and Avoid Imaging: SAR-ISAR Underground-Inside Building-Underfoliage Awareness Meteorological Electronic Support & Signal Intelligence Electronic Countermeasures-Attack Communications/Datalink/SATCOM
Mobility-Platform		
Fixed-Mobile-Portable Ground Airborne Manned/UAS Ships-Unmanned Maritime Systems Spacecraft-Airships Attended-Unattended Networks-Swarms		

tion was 36 percent, assuming a total amount of €4.8 billion which is half of the amount invested in 2006.[6] This comes at a time when the world is replete with social and regional convulsions, state failures and international tensions. This underscores the need to continue investing in military assets. As an example, Russia plans to invest $561 billion in modernizing its army and fleet plus $84 billion in modernizing production defence plants.[7]

RF SENSORS TAXONOMY

The complexity of an RF sensor system can be visualized through the non-extensive taxonomy summarized in ***Table 2.*** The higher the system performance required, the more complex the configuration, waveforms and/or functionalities, and likely higher costs. A challenging exercise in the current economic situation is to provide extraordinary performance that cannot be afforded and may even not be needed in order to be prepared for unpredictable scenarios.

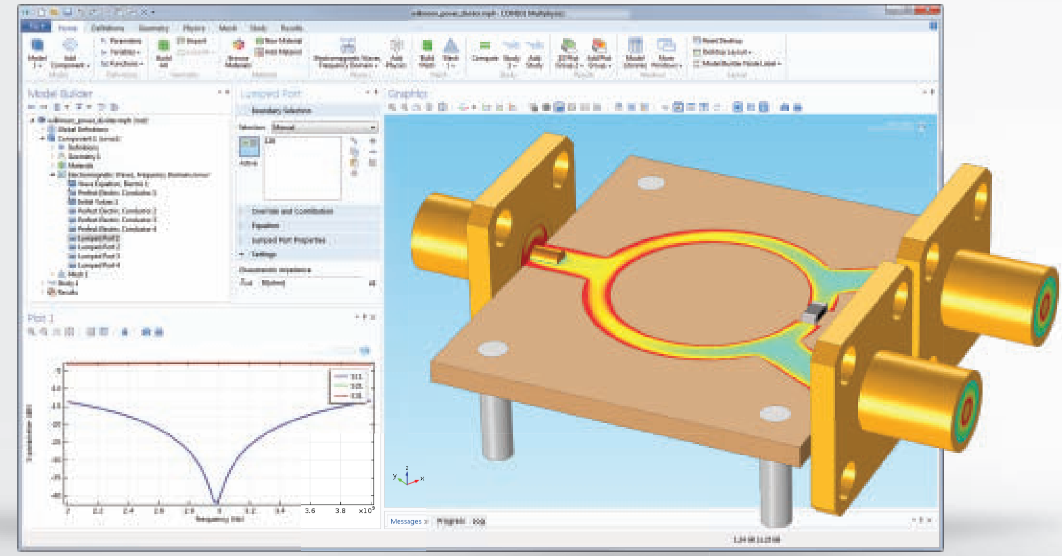
Increasing system complexity is required for several reasons, such as:

- The need for flexibility/plasticity due to changing environments and scenarios.
- The need for decreased SWaP-C attained through the development of modular and scalable multifunction systems based on flexible building blocks.
- The need for coexistence and resistance to interference with other systems, which has been exacerbated by the scarcity of RF spectrum, driving new concepts of adaptability, self-learning and anticipation.

These extremely complex systems require controlled methodologies to cover the whole life cycle in order to ensure proper management, cost limitation and control of risks. Systems engineering frameworks are required to provide the path for structured funding approaches, once proper system architectures are established.

This opens the door to both cooperation and competition of different kinds, with a specific approach to the management of intellectual property rights (IPR), which is often the cause for industry reluctance to participate in international research programs. It is essential for governments to continue their research efforts to take advantage of funding already invested. The establishment of hybrid standards (security-defence-commercial) defining these architectures can be the so-

RF DESIGN: Simulation results show the electric field distribution on top of the microstrip lines of a Wilkinson power divider. The S-parameters show input matching at 3 GHz and evenly divided power at the two output ports.



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lution for dual developments in smart and fruitful ways.

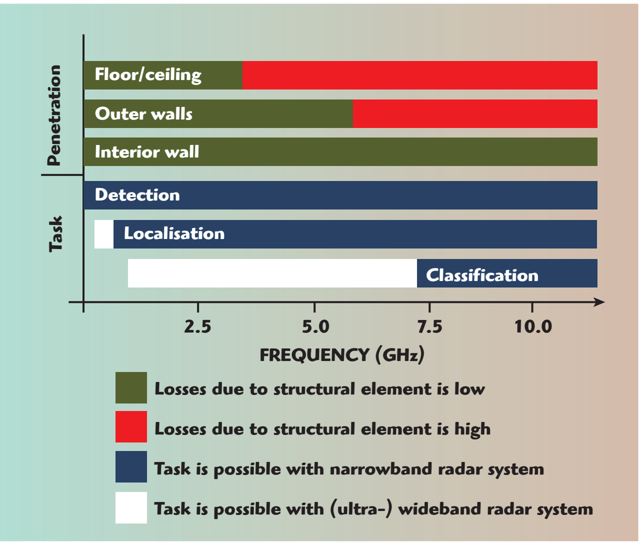
To deal with systems complexities, engineers must have a multidisciplinary profile and master systems engineering approaches. The critical defence professionals' skills are currently a matter of analysis at the agency.

SPECTRUM MANAGEMENT

The dispute for the frequency spectrum between military and commercial applications is a major issue. Global allocations of radio spectrum are agreed upon at the International Telecommunication Union (ITU) World Radiocommunication Conferences (WRC) for each ITU Region and incorporated in the Radio Regulations. The outcomes of WRCs have a treaty status.[8]

The right to use a fraction of the spectrum constrains sensor performance and implies the need to carefully select the frequency band and mitigation measures implemented to comply with the regulations. In that sense, it has to be determined long in advance that a system designed and manufactured for a specific application will have the necessary technical and legal support to meet its performance expectations, including the necessary spectrum protection.

The increase by an order of magnitude in commercial connected devices, estimated from 5 billion in 2010 to 50 billion in 2020,[9] portends a strong spectrum demand which may impact its availability for military operations. This is already being discussed, as new spectrum allocations are on the open agenda items for the next WRC in 2015.[10] Two examples are the mobile service for International Mobile Telecommunications (IMT) and the Wireless Avionics Intra-Communications (WAIC). Future band allocations and out-of-band mask requirements for communications systems could lead to degradation in the performance of military assets, mainly radars, working in these bands.

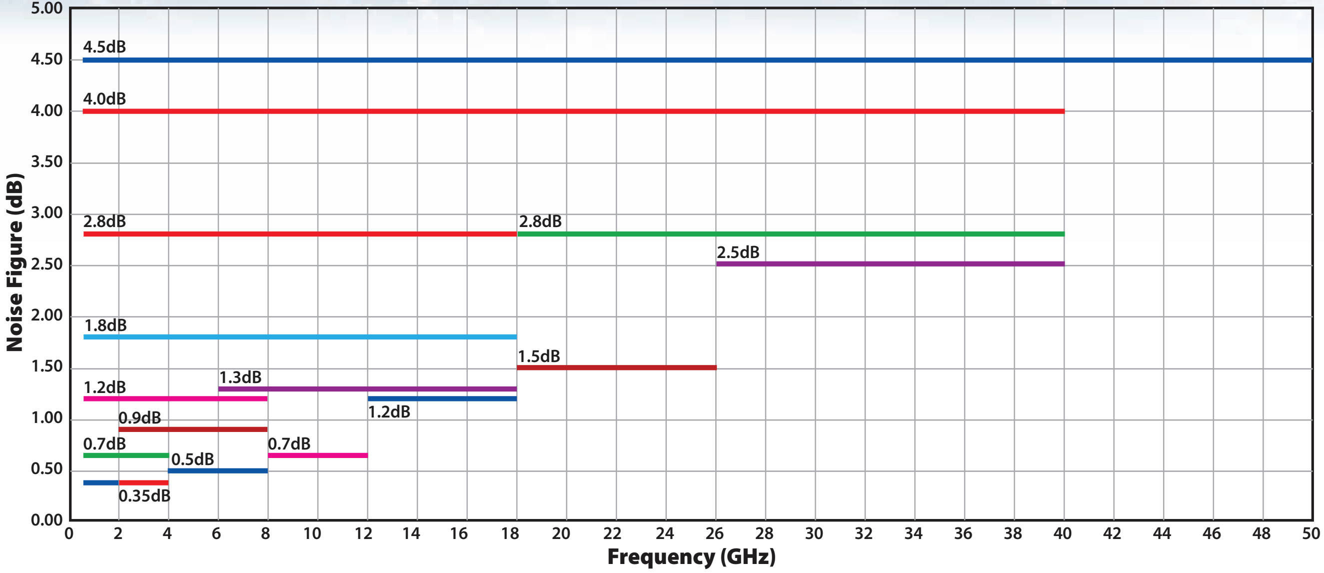


▲ *Fig. 1 Choice of frequency for TTW radar systems from the RIBA study.*

The lower frequency bands traditionally used for communications (HF, VHF and UHF) have gained renewed interest from radar systems designers. They provide over-the-horizon (OTH) capability, anti-stealth characteristics, higher penetration depth through foliage, ground and walls, and they look quite promising for perimeter detection and camp protection.

The ability of OTH to detect and track targets at distances between 1,000 and 4,000 km makes it very attractive for maritime surveillance and tactical ballistic missile (TBM) detection, even though the issue of low resolution must be solved and improved through adaptive and self-learning capabilities. The size of antennas is also raising environmental impact concerns. Radars working at frequencies below a GHz also have the advantage in that low observability measures are normally developed to reduce detectability at higher frequencies.

The spectrum needs of other applications that may be operational in the coming years must be anticipated. Non cooperative target recognition (NCTR) capability requires wide bandwidths, usually more than 250 MHz that should be made avail-



Noise Figure (dB)
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Frequency (GHz)

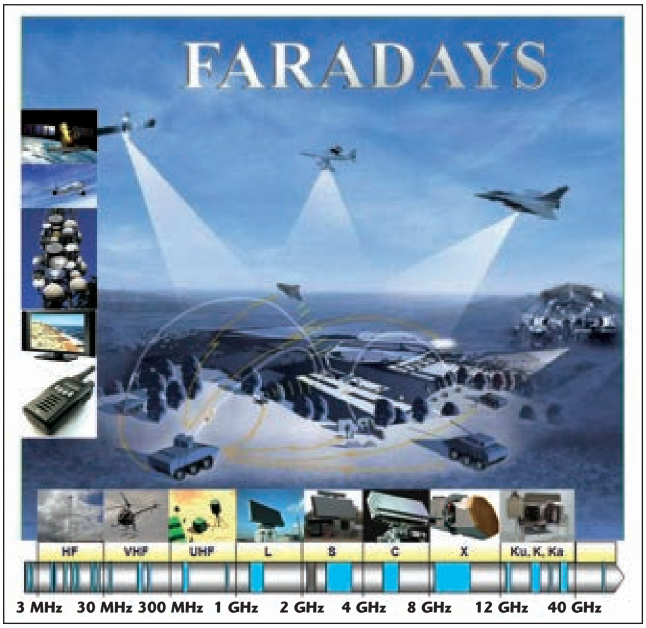

Fig. 2 FARADAYS project.

able in X-Band for airborne and L- or S-Bands for ground radars. Ultra-wideband (UWB) systems may need up to 3 GHz of bandwidth, enabling different dual (civilian-military) applications like through-the-wall (TTW) radar. ***Figure 1***, from the OB study RIBA,[11] shows the possibilities for frequency selection in TTW radar. Final selection must be done based on current regulations, leaving little room for development due to frequency availability.

The project FARADAYS (2010-2013) "Frequency allocation for radars in the coming years" has analyzed spectrum needs for future military radars providing several considerations and recommendations to ensure a proper functioning of future generation of RF sensor systems (see ***Figure 2***).

UAVS AND AESA ANTENNAS

Even with strong societal concerns about the use of remotely piloted aircraft (otherwise called drones or UAVs), these systems will be regulated and safety issues solved as we cannot neglect their benefits. The development of their payloads is an essential topic. EDA has contracted a study[12] that analyzes the accessible RPAS payloads market. Its conservative forecast value is €17.5 billion and the higher growth estimate is €23.6 billion for 2014-2035. Other estimates[13] considering a wider range of UAV payloads including EO/IR, SAR, SIGINT, EW and C4I Systems, and CBRN Sensors assess it at $3 billion per year currently, increasing to $5.6 billion annually by 2020.

Multifunction RF sensors integrate radar, communications, EW and/or detect and avoid. They will be part of the next generation of payloads and are optimally approached when they make use of AESA antennas as multifunction shared apertures operating in different frequency bands with different instantaneous bandwidths. This increases the capability of small platforms with low SWaP and reduces the number of apertures required. A proper resource manager module to organize and share resources is mandatory.

AESA antennas can be designed to be modular and scalable. This means that the BBs for the antenna can be used across many platforms and for different sized apertures which lowers production costs through economies of scale. It is unavoidable to mention the role of GaN as a breakthrough for AESA and the possibilities that it opens in this field.

The next step is to develop conformal AESA antennas, which is being analyzed by the EDA OB study UCAR.[14] AESA antennas have the potential to achieve low RCS. This feature is important for military UAVs designed for low observability (LO); and they do not compromise aerodynamics improving the capability of maneuvering, reducing fuel consumption and increasing endurance.

Another benefit of the AESA is graceful degradation, since only a common subsystem power supply or beam steering control failure can generate a general system failure. With

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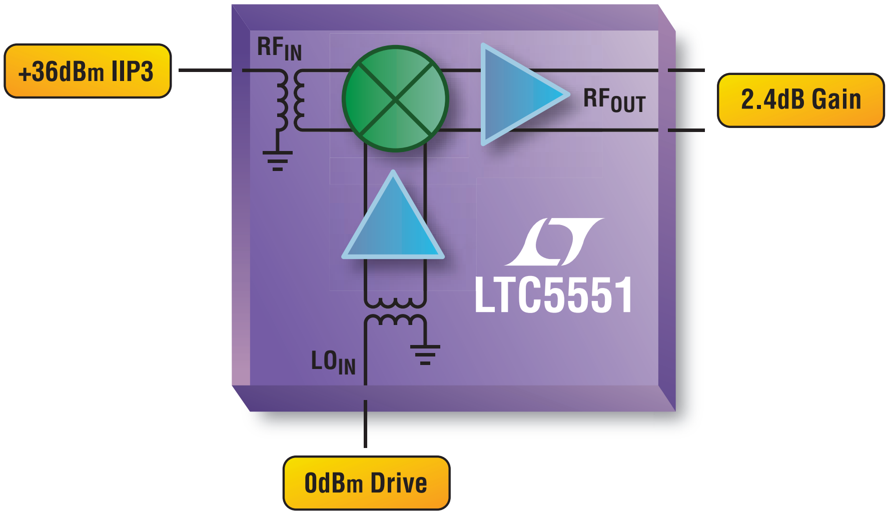

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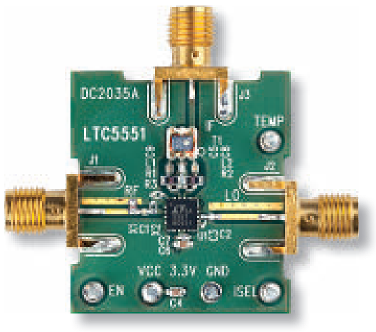

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proper monitoring and built in test (BIT) systems, the AESA can tolerate failure in some modules by using the working ones to provide acceptable results through adaptive beamforming.

Many more aspects of AESA design may be leveraged to address advanced applications including:

- Architectures
- Wideband arrays
- Low profile and bandwidth enhancement techniques like metamaterials or non-foster matching
- Conformal array pattern synthesis techniques
- RF-on-fiber
- Thermal management
- Manufacturing and integration
- True Time Delays (TTD) for wideband designs
- Cognitive methodologies and architectures to reduce the effect of interference through frequency nulling and other mitigation techniques.

NEW APPROACHES IN PROCESSING: COMPRESSIVE SENSING (CS)

The new paradigm for acquisition and sampling known as compressive sensing (CS) is attracting interest by promising enhanced system performance, while decreasing speed requirements for ADCs and DACs and saving on other hardware resources. The study "Radar Implementation of CS (RICS)"[15] is funded by the agency to assess its application in military RF sensors. One of the main objectives is establishing a framework to build future initiatives and serve as a guide and orientation to CS military applications.

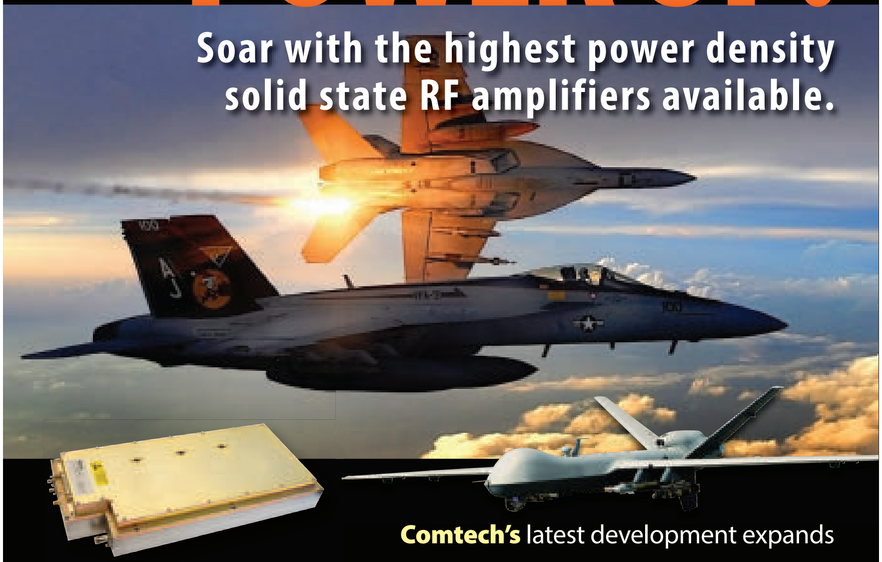
CS has a different structure than classical filtering approaches and exceeds their computational complexity. It is appropriate only when there is a potential improvement like obtaining higher resolution or reducing the number of measurement positions, antennas or radiating elements, sampling frequencies and grating lobes. The central point for the applicability of CS is the sparsity of a representation of the considered scenery, so it is fundamental to find a domain where this sparsity appears. It would be interesting to modify test devices to obtain measurements fitted to the architecture of CS reconstruction based on non-uniform sampling.

The assessment of CS results is being done by estimating the quality of reconstruction through Monte Carlo analyses, although more realistic error bounds are under consideration. CS approaches are usually much slower than classical filtering methods, so a real-time radar application is still challenging. Promising applications include active and passive inverse synthetic aperture radar (ISAR) imaging, direction of arrival (DOA) estimation, sparse array design procedures and receivers.

The CS-based receiver may open the way for new capabilities such as radar systems operating over large instantaneous bandwidths or even simultaneously on different narrow band carriers, instead of the time division methods normally used by surveillance and multifunctional radars. This would be particularly interesting for electronic protective measures (EPM).

EUROPEAN RF SENSORS SYSTEMS R&T COLLABORATION

EDA hosts a group of experts covering the subject of RF Sensors Sys-



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tems and Signal Processing that meets in the Capability Technological Area (CapTech) called RF Sensors Technologies (RFST) formerly known as IAP2. It belongs to the Unit Innovative Research (INR) from the Directorate European Synergies and Innovation (ESI).

The projects under the CapTech may be:

1. Funded through the operational budget (OB) of the agency where specific subjects are analyzed, state of the art is discussed and roadmaps for research proposed. Examples are the previously mentioned RICS and UCAR.
2. Ad Hoc Category B projects[16] common collaborative work funded by contributing members, normally 3 to 5, with values ranging an average of €2 to 4 million in a bottom-up approach.
3. Ad Hoc Cat A activities[17] involving a larger number of contributing members through a top-down approach. Funding is provided on a voluntary basis, typically over €10 million per project.

Multifunction: The projects STRATA and SIMPLE paved the way for the Scalable Multifunction RF Systems (SMRF) Program to build these sensors in a modular and scalable way. Under that umbrella, the AMBASSADOR project (2012-2013) was considering the modern architectural frameworks that must be used when defining complex systems as SMRF. A value assessment of model-based approach to product development predicted reductions in costs and time by about a third and the decrease of associated risks in development cost and schedule by about two thirds.

SIMCLAIRS (2009-2013) was an Innovation and Technology Partnership (ITP) aimed to de-risk and mature key enabling technology areas to achieve TRL 4 and to allow breakthroughs in the overall capabilities of compact multifunction RF sensors, identifying and quantifying the military benefits of this class of technologies (see ***Figure 3***).

This model of cooperation was very successful since there were two calls for competed projects allowing research suppliers from industry, SMEs and academia to contribute in the various technical domains. Subcontracts were awarded on the basis of merit with the most "competitive" bids securing funding.

A future project called SIRONA under a similar scheme is in preparation and will deal with the maturation of enabling hardware technologies for UAS payloads including both RF and electro-optical sensors.

NCTR: The use of imaging techniques like high resolution range profiles (HRRP) and inverse synthetic aperture radar (ISAR) is demonstrating the ability to address previous limitations and perform effectively in automatic target recognition (ATR) systems. In that sense, the ongoing project SPERI (2013-2015) includes research on superresolution for ATR on real images, CS and 2D space variant apodization. ACACIA is a 3-year project starting in 2014, that will focus on emerging waveforms, signal processing and feature-based classification techniques. MAPIS as follow up to JIP-ICET APIS will study, define and analyze a new system concept for implementing and demonstrating ISAR imaging capability in multistatic array passive radar to enable the capability of passive NCTR.

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MixAMC's can be used in a variety of different modes including frequency extension of spectrum analyzers and block up or down-conversion. These modules offer low-loss/low-noise performance with high instantaneous IF BW (up to 20GHz standard and 40GHz upon request).

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AMC Performance												
Test Port Power - Typical (dBm)	20	18/15	14	9	8	4	2	-2	-6	-10	-21	-23
Test Port Power - Minimum (dBm)	17	12/11	10	3	2	0	-5	-8	-12	-18	-30	-33
MixAMC Performance												
SSB Intrinsic Mixer Conversion Loss (dB)	9	11	11	12	12	12	14	14	15	17	20	30
Displayed Average Noise Level (dBm/Hz)	-150	-150	-150	-150	-150	-150	-150	-150	-150	-150	-150	-135
Maximum IF Bandwidth (GHz)	8	9	11	14	17	20	20	20	20	20	20	20

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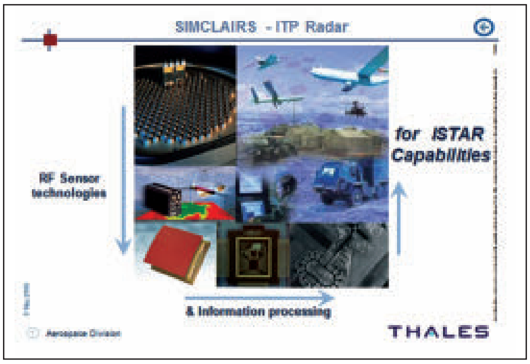

Fig. 3 SIMCLAIRS project.

Urban Sensors: TELLUS (2008-2012) explored technologies for solutions to difficult environments with smoke and dust, darkness, bad weather and concealed conditions, particularly in urban warfare scenarios looking for low cost, light weight and low power consumption for radar and ESM systems. TELLUS II is under preparation.

Biological: RFBIO is a 5-year project studying the biological effects of the military EM signals used by defence systems like radar or EW that are not covered by civil domain studies. A mechanistic approach will be established to try to understand the interactions between RF signals and biological systems. The projects already finished are worth more than €60 million and the estimates of the coming ones are around €30 million.

CONCLUSION

The EDA RF Sensors Technologies (RFST) community is dealing with the design and development of systems capable of performing challenging functions like detection, tracking and identification of difficult targets and RF signals surrounded by strong and changing clutter, and evolving scenarios congested with jamming, coexistence of a broad variety of sensors and spectrum limitations.

This implies the need for flexibility and adaptability bringing more complexity in terms of signal processing, demanding hardware, and test and validation requirements. The uncertainty in the number and experience of future engineers may be added as an issue of strong concern in the European supply chain and the need of multidisciplinary profiles and skills is highlighted.

Solutions should come from collaborative programs based on system engineering disciplines and their corresponding frameworks. Through model based system engineering, the design and development of RF sensors systems allows for continuous monitoring and management leading to decreased life cycle costs and more sustainable approaches. It also enables the development of modular, scalable and multifunction systems which are essential considering the constraints in size, weight, power and cost.

To enable this approach, standard architectures must be produced to foster collaboration through European programs managed through the instantiation of individual building blocks (BB) defined through standardized interfaces. With a tailored IPR scheme, the sensitivity of the BBs will be lower for the entire system, allowing competitive programs to demonstrate the concept on complete systems through integration of the BBs.


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We have provided an overview of the main EDA RFST (IAP2) CapTech Ad Hoc Cat B collaborative projects dealing with some of the main challenges that the RF sensors community is facing, describing specific points in terms of capability gaps and technical issues at system level. The key message is that international collaboration, like the one under the EDA framework, is a cost-effective way to deal with research topics covering capability gaps in times of limited defence budgets. ■

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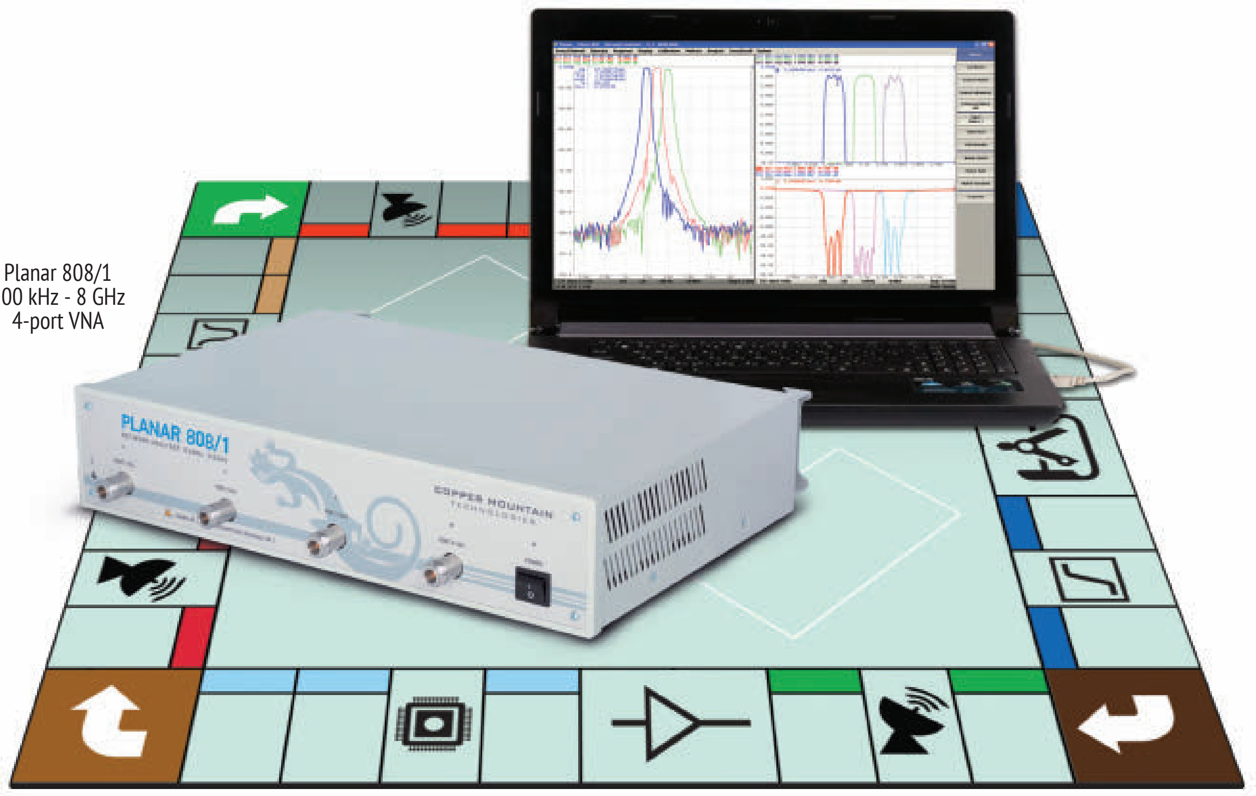
ExecutiveInterview

Dr. Ignacio Montiel-Sanchez, project officer of RF sensors technologies at the European Defence Agency. Visit www.mwjournal.com to read his in-depth interview.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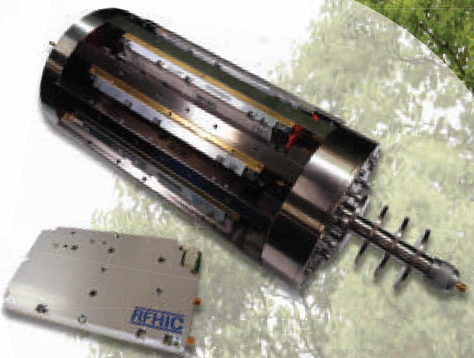

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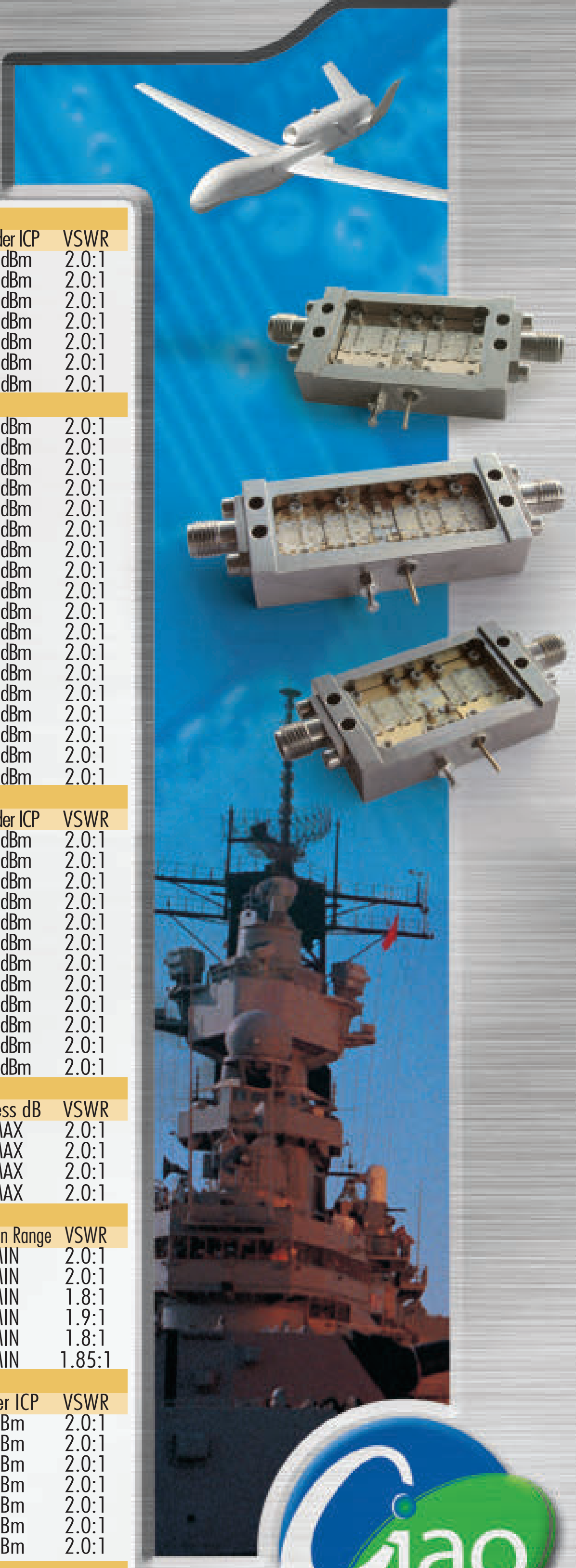

OCTAVE BAND LOW NOISE AMPLIFIERS

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure (dB)	Power-out @ P1-dB	3rd Order ICP	VSWR
CA01-2110	0.5-1.0	28	1.0 MAX, 0.7 TYP	+10 MIN	+20 dBm	2.0:1
CA12-2110	1.0-2.0	30	1.0 MAX, 0.7 TYP	+10 MIN	+20 dBm	2.0:1
CA24-2111	2.0-4.0	29	1.1 MAX, 0.95 TYP	+10 MIN	+20 dBm	2.0:1
CA48-2111	4.0-8.0	29	1.3 MAX, 1.0 TYP	+10 MIN	+20 dBm	2.0:1
CA812-3111	8.0-12.0	27	1.6 MAX, 1.4 TYP	+10 MIN	+20 dBm	2.0:1
CA1218-4111	12.0-18.0	25	1.9 MAX, 1.7 TYP	+10 MIN	+20 dBm	2.0:1
CA1826-2110	18.0-26.5	32	3.0 MAX, 2.5 TYP	+10 MIN	+20 dBm	2.0:1

NARROW BAND LOW NOISE AND MEDIUM POWER AMPLIFIERS

CA01-2111	0.4 - 0.5	28	0.6 MAX, 0.4 TYP	+10 MIN	+20 dBm	2.0:1
CA01-2113	0.8 - 1.0	28	0.6 MAX, 0.4 TYP	+10 MIN	+20 dBm	2.0:1
CA12-3117	1.2 - 1.6	25	0.6 MAX, 0.4 TYP	+10 MIN	+20 dBm	2.0:1
CA23-3111	2.2 - 2.4	30	0.6 MAX, 0.45 TYP	+10 MIN	+20 dBm	2.0:1
CA23-3116	2.7 - 2.9	29	0.7 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
CA34-2110	3.7 - 4.2	28	1.0 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
CA56-3110	5.4 - 5.9	40	1.0 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
CA78-4110	7.25 - 7.75	32	1.2 MAX, 1.0 TYP	+10 MIN	+20 dBm	2.0:1
CA910-3110	9.0 - 10.6	25	1.4 MAX, 1.2 TYP	+10 MIN	+20 dBm	2.0:1
CA1315-3110	13.75 - 15.4	25	1.6 MAX, 1.4 TYP	+10 MIN	+20 dBm	2.0:1
CA12-3114	1.35 - 1.85	30	4.0 MAX, 3.0 TYP	+33 MIN	+41 dBm	2.0:1
CA34-6116	3.1 - 3.5	40	4.5 MAX, 3.5 TYP	+35 MIN	+43 dBm	2.0:1
CA56-5114	5.9 - 6.4	30	5.0 MAX, 4.0 TYP	+30 MIN	+40 dBm	2.0:1
CA812-6115	8.0 - 12.0	30	4.5 MAX, 3.5 TYP	+30 MIN	+40 dBm	2.0:1
CA812-6116	8.0 - 12.0	30	5.0 MAX, 4.0 TYP	+33 MIN	+41 dBm	2.0:1
CA1213-7110	12.2 - 13.25	28	6.0 MAX, 5.5 TYP	+33 MIN	+42 dBm	2.0:1
CA1415-7110	14.0 - 15.0	30	5.0 MAX, 4.0 TYP	+30 MIN	+40 dBm	2.0:1
CA1722-4110	17.0 - 22.0	25	3.5 MAX, 2.8 TYP	+21 MIN	+31 dBm	2.0:1

ULTRA-BROADBAND & MULTI-OCTAVE BAND AMPLIFIERS

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure (dB)	Power-out @ P1-dB	3rd Order ICP	VSWR
CA0102-3111	0.1-2.0	28	1.6 Max, 1.2 TYP	+10 MIN	+20 dBm	2.0:1
CA0106-3111	0.1-6.0	28	1.9 Max, 1.5 TYP	+10 MIN	+20 dBm	2.0:1
CA0108-3110	0.1-8.0	26	2.2 Max, 1.8 TYP	+10 MIN	+20 dBm	2.0:1
CA0108-4112	0.1-8.0	32	3.0 MAX, 1.8 TYP	+22 MIN	+32 dBm	2.0:1
CA02-3112	0.5-2.0	36	4.5 MAX, 2.5 TYP	+30 MIN	+40 dBm	2.0:1
CA26-3110	2.0-6.0	26	2.0 MAX, 1.5 TYP	+10 MIN	+20 dBm	2.0:1
CA26-4114	2.0-6.0	22	5.0 MAX, 3.5 TYP	+30 MIN	+40 dBm	2.0:1
CA618-4112	6.0-18.0	25	5.0 MAX, 3.5 TYP	+23 MIN	+33 dBm	2.0:1
CA618-6114	6.0-18.0	35	5.0 MAX, 3.5 TYP	+30 MIN	+40 dBm	2.0:1
CA218-4116	2.0-18.0	30	3.5 MAX, 2.8 TYP	+10 MIN	+20 dBm	2.0:1
CA218-4110	2.0-18.0	30	5.0 MAX, 3.5 TYP	+20 MIN	+30 dBm	2.0:1
CA218-4112	2.0-18.0	29	5.0 MAX, 3.5 TYP	+24 MIN	+34 dBm	2.0:1

LIMITING AMPLIFIERS

Model No.	Freq (GHz)	Input Dynamic Range	Output Power Range Psat	Power Flatness dB	VSWR
CLA24-4001	2.0 - 4.0	-28 to +10 dBm	+7 to +11 dBm	+/- 1.5 MAX	2.0:1
CLA26-8001	2.0 - 6.0	-50 to +20 dBm	+14 to +18 dBm	+/- 1.5 MAX	2.0:1
CLA712-5001	7.0 - 12.4	-21 to +10 dBm	+14 to +19 dBm	+/- 1.5 MAX	2.0:1
CLA618-1201	6.0 - 18.0	-50 to +20 dBm	+14 to +19 dBm	+/- 1.5 MAX	2.0:1

AMPLIFIERS WITH INTEGRATED GAIN ATTENUATION

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure (dB)	Power-out @ P1-dB	Gain Attenuation Range	VSWR
CA001-2511A	0.025-0.150	21	5.0 MAX, 3.5 TYP	+12 MIN	30 dB MIN	2.0:1
CA05-3110A	0.5-5.5	23	2.5 MAX, 1.5 TYP	+18 MIN	20 dB MIN	2.0:1
CA56-3110A	5.85-6.425	28	2.5 MAX, 1.5 TYP	+16 MIN	22 dB MIN	1.8:1
CA612-4110A	6.0-12.0	24	2.5 MAX, 1.5 TYP	+12 MIN	15 dB MIN	1.9:1
CA1315-4110A	13.75-15.4	25	2.2 MAX, 1.6 TYP	+16 MIN	20 dB MIN	1.8:1
CA1518-4110A	15.0-18.0	30	3.0 MAX, 2.0 TYP	+18 MIN	20 dB MIN	1.85:1

LOW FREQUENCY AMPLIFIERS

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure dB	Power-out @ P1-dB	3rd Order ICP	VSWR
CA001-2110	0.01-0.10	18	4.0 MAX, 2.2 TYP	+10 MIN	+20 dBm	2.0:1
CA001-2211	0.04-0.15	24	3.5 MAX, 2.2 TYP	+13 MIN	+23 dBm	2.0:1
CA001-2215	0.04-0.15	23	4.0 MAX, 2.2 TYP	+23 MIN	+33 dBm	2.0:1
CA001-3113	0.01-1.0	28	4.0 MAX, 2.8 TYP	+17 MIN	+27 dBm	2.0:1
CA002-3114	0.01-2.0	27	4.0 MAX, 2.8 TYP	+20 MIN	+30 dBm	2.0:1
CA003-3116	0.01-3.0	18	4.0 MAX, 2.8 TYP	+25 MIN	+35 dBm	2.0:1
CA004-3112	0.01-4.0	32	4.0 MAX, 2.8 TYP	+15 MIN	+25 dBm	2.0:1

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Raytheon Demonstrates Successful Prototyping of AESA/GaN Technologies into Patriot Radar

Raytheon Co. demonstrated their successful prototyping of active electronically scanned array (AESA) and Gallium Nitride (GaN) technologies into the U.S. Patriot Air and Missile Defense System radar. In addition to enabling future 360 sensor coverage, these technologies will significantly increase the defended area and decrease the time to detect, discriminate and engage threats. The introduction of GaN-based AESA technologies will also further improve reliability and lower the life cycle costs for the Patriot radar, beyond what has already been achieved with other recent Patriot radar improvements.

Source: U.S. Army photo

"Raytheon is a leader in airborne, sea-based and ground-based radars and we continue to invest in research and development to further mature radar technology. GaN-based AESA technologies represent the future of ground-based sensors and will have future application to Raytheon's entire sensor portfolio," said Ralph Acaba, vice president of Integrated Air and Missile Defense at Raytheon's Integrated Defense Systems business. "Along with the Patriot radar, the entire Patriot system has kept pace with the latest technological advances to ensure over match against current and evolving threats. The Patriot that's currently in production and fielded is the most advanced air and missile defense system available today."

Selex ES Awarded Multi-Million Euro Contract from Saab for Raven AESA Radar

A multi-million euro contract has been awarded to Finmeccanica - Selex ES by defence and security company Saab to supply the Raven ES-05 AESA radar for Saab's Gripen Next Generation (NG) fighters.

A NATO-interoperable, multi-role fighter designed for the future network-centric warfare environment, Gripen NG will provide superior situation awareness thanks to a number of Finmeccanica – Selex ES products. In addition to the Raven ES AESA radar, the company will also provide the Skyward-G Infrared Search & Track (IRST) passive sensor and Identification Friend-or-Foe (IFF) system, both of which will be contracted for in the next few months.

Finmeccanica - Selex ES's participation in the Gripen NG programme dates back to 2009, when an agreement was signed with Saab for the development of the Raven ES AESA radar. This was followed in 2010 by the selection of the Skyward-G IRST sensor and the IFF system.

A production-standard Raven AESA radar is now installed on Gripen demonstration aircraft, while flight tests with the Skyward-G IRST have been underway since March, achieving excellent results and demonstrating the value of a passive sensor as an integral part of a weapons system. The IFF system will be delivered later in the year.

In a recent development, Finmeccanica – Selex ES's new BriteCloud Expendable Active Decoy (EAD) has been chosen as an electronic warfare option for the Gripen NG and all other versions of the aircraft. Currently, the BriteCloud EAD is the only product of its type on the market and Saab will be the first partner to offer the new decoy, boosting the desirability of Gripen NG for new customers. Live BriteCloud trials on-board the platform are expected to take place by the end of 2014.

Currently, Gripen C/D versions are in service in Sweden, South Africa, Hungary, Czech Republic and Thailand. Gripen NG is in full scale development for Sweden and has been down-selected and in final negotiations for Brazil.

GD Awarded $25 M by LM for Continued Work on USAF GPS III Program

General Dynamics Advanced Information Systems, a business unit of General Dynamics, was awarded a $25.4 million full-production contract from Lockheed Martin to support the U.S. Air Force Global Positioning System (GPS) III Network Communications Element (NCE) for space vehicles seven and eight (SV 07-08). The Air Force's next-generation GPS III satellites will improve position, navigation and timing services as well as provide advanced anti-jam capabilities yielding superior system security, accuracy and reliability.

"For more than 50 years, we have been a premier provider of spacecraft communications and navigation equipment for the nation's military and government agencies," said Carlo Zaffanella, vice president and general manager of Intelligence, Surveillance and Reconnaissance at General Dynamics Advanced Information Systems. "Our continued close work with Lockheed Martin on the GPS III program, coupled with our in-depth mission understanding, allows us to provide the Air Force with the next-generation of reliable and affordable solutions to replace the aging constellation of GPS satellites currently in orbit."

General Dynamics' NCE components provide the communications functions for the GPS III satellites, including the ground-to-space command and control channel, the

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space-to-space inter-satellite channel and the command and telemetry communications channels within each satellite.

Compared to prior GPS vehicles, the Air Force's GPS III satellites will deliver three times better accuracy, provide up to eight times more powerful anti-jamming capabilities and include enhancements that extend spacecraft life by 25 percent. GPS III-series satellites also will carry a new civil signal designed to be interoperable with other international global navigation satellite systems, enhancing civilian-user connectivity. The majority of the work under contract will be performed at the General Dynamics Advanced Information Systems facilities in Scottsdale, Ariz., and Bloomington, Minn.

Exelis Delivers Latest EW Technology for U.S. Navy F/A-18 Aircraft

Exelis has successfully delivered to the U.S. Navy the first nine full rate production, next-generation electronic self-protection systems for F/A-18 fighter aircraft. The ALQ-214(V)4/5 is the latest variant of the onboard jammer subsystem in the Integrated Defensive Electronic Countermeasures (IDECM) suite.

Through a series of enhancements, including miniaturization and improved electronics packaging, the ALQ-214(V)4/5 can be installed on F/A-18E/F Super Hornets as well as – for the first time – on F/A-18C/D Hornets. This will help ensure that both types of aircraft and their crews are protected from modern, dynamic radio frequency threats.

"With enhanced software programmability and reduced size and weight, our latest system ensures that naval aviators stay ahead of emerging electronic threats," said Joe Rambala, vice president and general manager of the Exelis integrated electronic warfare systems business area. "Exelis has helped advance the Navy's electronic warfare mission for more than 16 years, and this milestone extends our record to 198 months of on-time delivery to the IDECM program."

The ALQ-214 is produced at the Exelis Electronic Systems (ES) facility in Clifton, N.J.

Source: U.S. Navy photo

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InternationalReport

Richard Mumford, International Editor

Cobham Receives AGP Funds for HARNet Aircraft Project

Cobham has received funding from the UK Aerospace Growth Partnership (AGP) as part of a Thales led effort to develop smaller, lighter, more flexible and capable future communications systems for civil aircraft. The £6.4 million AGP award will fund the Harmonised Antennas, Radios and Networks (HARNet) strategic research programme to develop the radio techniques and technologies required for an Integrated Modular Communications (IMC) system for civil aircraft using software defined radio technology.

If successful and adopted by civil aircraft original equipment manufacturers (OEM), IMC would mean less equipment to be installed in new aircraft, freeing up critical space, reducing weight and using less fuel. For the airlines, reduced weight means reduced costs, higher reliability and safety. Greater fuel efficiency could mean future airliners would increase passenger capability, improve operational efficiency and reduce both noise and CO_2 emissions.

As part of this project, three Cobham businesses located in England will participate with support from the University of Southampton and Queen Mary University of London. The Cobham contribution will take forward advanced antennas and high data bandwidth MESH radios.

> ...freeing up critical space, reducing weight and using less fuel.

Pete Raby, Cobham Communications and Connectivity sector president who is responsible for all three Cobham businesses said: "Cobham is very pleased and excited to participate in this project. Our antennas and radios are already very advanced in terms of their small size, weight and superior capability, but this project will allow us to investigate advanced concepts and possibly find additional savings that could lead to further improvements in future civil aircraft."

COST Association and EC Sign Framework Partnership Agreement

The COST Association and the European Commission have signed a Framework Partnership Agreement (FPA) for a new period of seven years for the COST intergovernmental framework operation during the EU Framework Programme Horizon 2020. COST is an intergovernmental framework for European Cooperation in Science and Technology, enabling the coordination of nationally-funded research on a European level. This agreement acknowledges the role that COST will play in Horizon 2020, given its contribution to strengthening Europe's research and innovation capacities.

In particular, COST will dedicate 50 percent of its overall budget to activities involving researchers from Inclusiveness Target Countries. By fully developing and implementing its Inclusiveness Policy, COST aims to increase such researchers' participation in COST Actions and activities, in relation to the European Commission's approach to widening participation.

COST Actions feature three key principles: openness, excellence and inclusiveness, achieved by fostering new ideas, sharing knowledge and an output orientation. This is how COST has managed to make significant contributions to the competitiveness and the overall development of the European research landscape, thus contributing to Europe's Innovation Union goals.

> ...strengthening Europe's research and innovation capacities.

The FPA comes in response to the major challenges of Horizon 2020, namely Europe in a changing world – inclusive, innovative and reflective Societies and Spreading Excellence and widening participation. In these cases, COST is referred to as a key contributor to the Programme strategic objectives, given its support particularly towards pan-European cooperation in science and technology.

The objectives that COST has set forth in order to help tackle these challenges while fulfilling its mission are: joining research efforts and developing common S&T programmes by coordinating nationally funded research activities led by pan-European, high quality, collaborative S&T networks; building capacity by providing networking and leadership opportunities for emerging talents and thereby strengthening and building up excellent S&T communities; addressing societal questions by promoting trans-disciplinary, new approaches and topics and identifying early warnings of unforeseen societal problems aimed at contributing to Societal Challenges; strengthening the COST Inclusiveness Policy by fostering better access and integration for researchers from less research-intensive countries into the knowledge hubs of the European Research Area aimed at contributing to the Widening Pillar of Horizon 2020.

Galileo Satellites 5 and 6 Launched

VIEW VIDEO

The latest satellites in Europe's Galileo satellite navigation system were launched on 21 August, ushering in the system deployment phase and paving the way for the start of initial services. Galileo SATs 5 and 6 were launched from Europe's Spaceport in French Guiana on top of a Soyuz rocket. They are expected to become operational, after initial in-orbit testing, in the autumn.

> ...the constellation will be gradually deployed...

The two satellites will join the four Galileo 'in-orbit validation' satellites already in space. Launched in pairs in October 2011 and October 2012, these four satellites

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– the minimum required to obtain a position fix – served to demonstrate and validate the space and ground segments of the system.

Galileo SATs 7 and 8 are scheduled to follow end of year 2014. Then the constellation will be gradually deployed with six to eight satellites launched per year using a series of Soyuz and Ariane launches from Kourou, along with remaining elements of the ground network.

155 SMEs to Receive Funding Under EU SME Instrument

The European Commission has announced the first results of its new €3 billion SME Instrument, launched under Horizon 2020 to help innovative small firms get ideas from the lab to the market. In total, 155 SMEs from 21 countries (EU Member States or countries associated to Horizon 2020) will each receive €50,000 to finance feasibility studies to develop their innovation strategy. In addition, SMEs can benefit from up to three days of business coaching.

Spanish SMEs were particularly successful in the first round, with 39 proposals selected, followed closely by SMEs from the UK and Italy. In total, there were 2,666 applications for the first grants.

Máire Geoghegan-Quinn, European Commissioner for Research, Innovation and Science, said: “The response to the new SME Instrument is encouraging. There is clearly demand out there for this kind of support. I hope many of the business plans being financed will mature to become real products and services, generating growth and jobs for our economies. We need our champions of innovation to grow!”

> “We need our champions of innovation to grow!”

The SME Instrument is a key element of the funding for small businesses available under Horizon 2020. Worth around €3 billion over seven years, it offers fast and simple grants for business innovation feasibility studies (Phase 1) and demonstration projects (Phase 2). Investment-mature concepts can benefit from business development advice and other support services (Phase 3). Around 645 projects (under Phase 1 and 2) should be funded in 2014, rising to 670 in 2015.

Through the SME Instrument the European Union wants to finance the most innovative small companies, with a high growth potential. The application process is easy but only the very best projects can expect to receive funding. Eligible topics are set out in the Horizon 2020 Work Programme on ‘Innovation in SMEs’.

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CMA-545+	0.05-6	15	20	37	1	3	4.95
NEW CMA-5043+	0.05-4	18	20	33	0.8	5	4.95
NEW CMA-545G1+	0.4-2.2	32	23	36	0.9	5	5.45
NEW CMA-162LN+	0.7-1.6	23	19	30	0.5	4	4.95
NEW CMA-252LN+	1.5-2.5	17	18	30	1	4	4.95

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Growth of Cellular Radio Components Likely to Accrue to Top Suppliers

Over the next five years, growth in cellular phones and related devices will push the market for cellular radio components to more than $45 billion led by basebands, power amplifiers and related front end components, as detailed in “Cellular Radio Components Still On a Healthy Trajectory Through 2018” a new report from Strategy Analytics.

According to Christopher Taylor, director, “Total production of cellular terminals surpassed 2.3 billion units in ‘13, resulting in an increase in sales of radio components to more than $27 billion. Baseband processors will continue to make up the biggest piece of the bill of material in phones and related terminals, but carrier aggregation, diversity and MIMO in support of higher-speed LTE will put power amplifiers, diversity receive modules, antenna tuners and drain modulators on a strong growth trajectory as well.”

> “In 2018, LTE devices will represent more than 70 percent of the cellular component market, which will include RF switches, filters, duplexers... and other front end components.”

According to Stephen Entwistle, head of Strategic Technologies, “In 2018, LTE devices will represent more than 70 percent of the cellular component market, which will include RF switches, filters and duplexers in new partitioning schemes with PAs and other front end components. Suppliers of RF front ends that do not work hard to provide OEMs with these new parts face marginalization.

Qualcomm Dumps Package in First CMOS PA Offering

The highly promoted RF PA devices from Qualcomm are starting to hit production phones. The first phone built with the Qualcomm PAs utilizes both the QFE2320 (for low-band) and QFE2340 (for high-band) multi-mode/multi-band (MMMB) PAs. These devices, along with the other front end components, are new offerings for Qualcomm which has shied away from the PA area up until now. Qualcomm introduced some expected developments including the first CMOS MMMB PA in mass-production and the first CMOS integrated PA/Switch in mass-production. However there was one big surprise.

“The unannounced characteristic, which is also an industry first, is not so much something that is there, but something that is not: the QFE2340 does not have a package. The PA is directly attached to the PCB—a technique that is common in the power management and connectivity realms but thus far has eluded the PA offerings in the industry,” comments Jim Mielke, VP of engineering at ABI Research.

The ~3 mm × 2 mm QFE2340 has a number of good merits but traditional PA providers (TriQuint, RFMD and Skyworks) have been continuously improving their offerings too. Their product lines include MMMB PAs that support both high-band and low-band in a single package; with performance enhancements GaAs still offers over CMOS in high-power modes.

GPS Tracking Devices to Break $3.5 Million in 2019

VIEW VIDEO

The GPS personal tracking market has always had huge potential yet it has faced huge barriers around awareness and RoI, expensive devices, cellular subscriptions, indoor location and severe regionalization and fragmentation. As a result the market has never been able to scale sufficiently to lowering costs and creating revenue to support much needed marketing/advertising campaigns.

In its latest report, “Personal Location Device and Application Markets,” ABI Research considers adoption of GPS devices and smartphone applications across family, elderly/health, lone worker, pets, and personal assets. Senior analyst Patrick Connolly commented, “The potential of this market continues to draw investment and interest. Over the last 12 months, there has been a host of companies entering this space, as well as a steady stream of start-ups. Start-ups like hereO and Estimote are buoyed by wearables and iBeacons; enterprise/commercial GPS companies like Quattro Wireless and Masternaut are moving into areas such as mobile workforce management and lone worker applications; and the connected home market will evolve to support personal protection across children, pets, cars, etc. e.g. Life 360/ADT. Carriers eager to solve the problem of saturated markets have begun to reconsider this space with the dawn of GPS-enabled wearables and the Internet of everything.”

This is reflected in a significant increase in GPS IC shipments into this space over the past year, as low cost GPS units become adopted worldwide for a host of applications. iBeacons are set to be a major driver, solving the issue of indoor location, while also creating a low cost entry point for both OEMs and consumers. With BLE beacons forecast to penetrate into all aspects of life over the next three years, consumer awareness and acceptance will quickly emerge.

> “Over the last 12 months, there has been a host of companies entering this space, as well as a steady stream of start-ups.”

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The Internet of Things Will Keep Demand for Stand-Alone Bluetooth ICs Strong

The share of stand-alone Bluetooth ICs will be about 40 percent by the end of 2014, down from 42 percent in 2013, and by the end of 2019 that share will remain at 40 percent. The steady market share of stand-alone Bluetooth IC is being maintained by both traditional device categories which consist of handsets, tablets, and PCs, and new growth categories including wearables, sports and fitness equipment and smart home nodes. “End user products such as smartphones and PCs have been shifting away from stand-alone solutions for some time now, and smartphones have shifted to integrated platforms with Bluetooth as well,” said research director, Philip Solis. “On the other hand, there is a growing long tail of devices around the Internet of Things (IoT) that will gravitate towards stand-alone Bluetooth in many cases. The end result is that stand-alone Bluetooth ICs will remain steady in share and grow with the overall market.”

Handsets, smartphones and feature phones are a dominant part of the Bluetooth chipset market and will remain so, but to a lesser degree throughout the forecast period. “Handsets comprised 62 percent of the market for Bluetooth ICs in 2013 and this will fall to 53 percent in 2019,” added Solis. This is a big part of the reason why over 70 percent of Bluetooth ICs will be Smart Ready with a much smaller portion being Smart. These trends play into the hands of dominant vendors like Broadcom and Qualcomm, but still leave plenty of room for smaller Bluetooth chipset vendors. “The IoT will provide additional growth opportunities for all vendors, but while the larger vendors tend to work with high volume customers and products, it is the smaller vendors that will be able to take advantage of the long tail of opportunities.”

> “There is a growing long tail of devices around the Internet of Things (IoT) that will gravitate towards stand-alone Bluetooth...”

Bluetooth has become ubiquitous in end user devices, which has been critical for the growth of the technology in the IoT. However, one of the biggest growth markets for stand-alone and combo Bluetooth ICs – smart home nodes – will also have many competing wireless connectivity technologies. Bluetooth’s lack of mesh networking capabilities (aside from a proprietary implementation from CSR) might put it at a disadvantage against 802.15.4-based solutions.

Around the **Circuit**

Barbara Walsh, Multimedia Staff Editor

MERGERS & ACQUISITIONS

Mentor Graphics Corp. announced the acquisition of **XS Embedded GmbH** (XSe), a technology leader in the creation of automotive system architectures and hardware reference platforms. XSe has over ten years of direct experience in the automotive electronics design industry across twenty automotive programs that combine hardware and software expertise. XSe brings a pioneering approach to accelerate system design and verification by providing automotive-grade hardware and software to reduce the time to SOP. Mentor is now well positioned to address the cross-functional collaboration needs required to address the trends towards integration of Advanced Driver Assistance Systems (ADAS), Driver Information and Infotainment domains.

GigOptix Inc., a leading supplier of advanced high speed semiconductor components for use in long-haul, metro, Cloud connectivity, data centers, consumer electronics links and interactive applications, through optical and wireless communications networks, announced that it has signed a definitive agreement to acquire for cash only, by way of assuming specified liabilities, substantially all of the assets of **Tahoe RF Semiconductor Inc.**, a provider of RF/analog RFICs, IPs, and fully integrated systems and subsystems on a chip.

COLLABORATIONS

Crane Aerospace & Electronics, Power Solutions will be supplying the Auto-Transformer Rectifier Unit (ATRU) to provide reliable power conversion for the **Rockwell Collins** Horizontal Stabilizer Control Unit (HSCU) supplied to Embraer. The HSCU will be utilized on the Embraer E2 E-Jet family of medium range aircraft, with introduction planned by 2018. In other news, they have announced the appointment of Steve Barr as vice president operations for the electronics group of Crane Aerospace & Electronics. Located in Redmond, Wash., Barr will be responsible for operations and supply chain for all electronics group locations.

NEW STARTS

Keysight Technologies Inc. announced the electronic measurement business of **Agilent Technologies** has begun operating under the Keysight name. It will remain a wholly owned subsidiary of Agilent Technologies until early November when the separation is expected to be completed and Keysight begins trading on the NYSE under the symbol KEYS. Keysight is a market leader holding the number one position in its industry segments of communications; aerospace and defense; and industrial, computers and semiconductors. Keysight's separation from Agilent was announced in September 2013.

AMC Solutions LLC, a leader in cost-effective marketing communications solutions for RF and microwave companies, is offering new services in North America and Europe. AMC Solutions supports new and expanding companies by growing sales, establishing markets and enhancing customer relationships. Visit AMC at www.amcsolutions.info.

Isola Group S.a r.l. announced that its technical staff would offer a conversion service for PCB fabricators of RF and millimeter-wave applications. This global 24-hour design review service will enable PCB fabricators to quickly and cost-effectively transition their current RF substrates to Isola's RF products and eliminate the production backlogs caused by the current shortages of RF substrates. The company also announced that it has increased production of its RF-related materials; Isola's materials are in stock and ready to ship.

ACHIEVEMENTS

Empower RF Systems announced the approval of a patent on "Broadband linearization module and method." New communication services and the use of complex waveforms have created a demand for highly linearized power amplifiers. Deviations from linearity show up as spectral distortions and/or modulation quality degradation (EVM) in the output of these amplifiers—that is, undesired energy, not contained in the original signal, inside or outside the frequency band of interest. Linearization techniques seek to reduce these distortions, allowing an amplifier to operate at its best spectral and power efficiency for the specific application.

The IEEE Region 6 Southern Area Award for Outstanding Corporate Service to the Engineering Community for 2014 was recently presented to **Maury Microwave**. The award was presented at the Maury Microwave facility in Ontario, Calif. to Greg Maury, CEO, and members of his senior engineering and management staff. The IEEE Foothill Section presenters were Max Cherubin, IEEE Foothill Section MTT/APS Chapter Chair, and Frank G Freyne, IEEE Foothill Section Chair. The IEEE especially acknowledged the technical presentations and numerous student group tours conducted at the Maury Microwave facility over the past two years.

Coaxial Components Corp. also known worldwide as **Coaxicom**, announced that it has received AS9100C Certification after satisfying an audit of rigorous process control, quality management, and risk management required for registration.

Dynawave Cable Inc. announced certification to the AS9100 quality management system by audit firm UL DQS Inc. AS9100 certification requires companies to demonstrate practices and capabilities which meet the demanding, complex and unique requirements of the defense and commercial aerospace industry.

CONTRACTS

Harris Corp. has received a $15 million order to deliver its latest wideband handheld tactical radio to a country in the

For More Information

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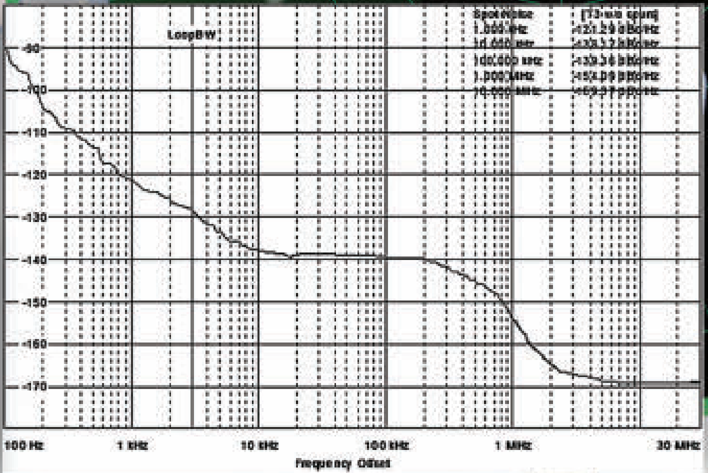
PHASE LOCKED DRO

Typical Phase Noise	Offset	Phase Noise
	@ 100 Hz	-95 dBc/Hz
	@ 1 kHz	-121 dBc/Hz
	@ 10 kHz	-136 dBc/Hz
	@ 100 kHz	-136 dBc/Hz
	@ 1 MHz	-154 dBc/Hz
	@ 10 MHz	-168 dBc/Hz



Frequency	10.24 GHz
AC Power (Normal Operation)	Voltage: 120 VAC @ 250 mA Voltage: 240 VAC @ 235 mA
Output Power	+10 dBm (Typ.)
Spurious & Ref. Sideband	75 dBc (Typ.)
Harmonic Suppression	30 dBc (Typ.)
Temperature	+25 °C (Room Temperature)
Warm-up Time	15 Minutes
Internal VCO	SMC Model: DRO1024
Output Impedance	50 Ohms (Nominal)
Output Connector	Type N Female

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Middle East. Harris is supplying this nation with the RF-7850M handheld, a multi-band, multi-mission radio that provides advanced tactical communication capabilities. The radio offers a new embedded interface that gives users access to a library of applications that provide situational awareness, tactical messaging, file transferring and radio configuration support from a standard web browser. The interface is fully customizable through a software-development kit, simplifying the process of creating and distributing new applications.

Microsemi Corp., a provider of semiconductor solutions differentiated by power, security, reliability and performance, announced it was awarded a $12 million contract from a major U.S. Department of Defense (DoD) supplier to manufacture key receiver subsystems for smart munitions.

Communications & Power Industries LLC (CPI) has received a contract totaling more than $6 million to provide power couplers for the European XFEL superconducting linear accelerator. Power couplers, which transmit the electromagnetic energy generated by a high-power microwave source, are critically important components in all superconducting accelerators, as they provide the vacuum and thermal interface between the evacuated superconducting cavity and waveguide components. CPI's power couplers will be used to inject high-power microwave signals into multiple cryogenic cavities that form the European XFEL.

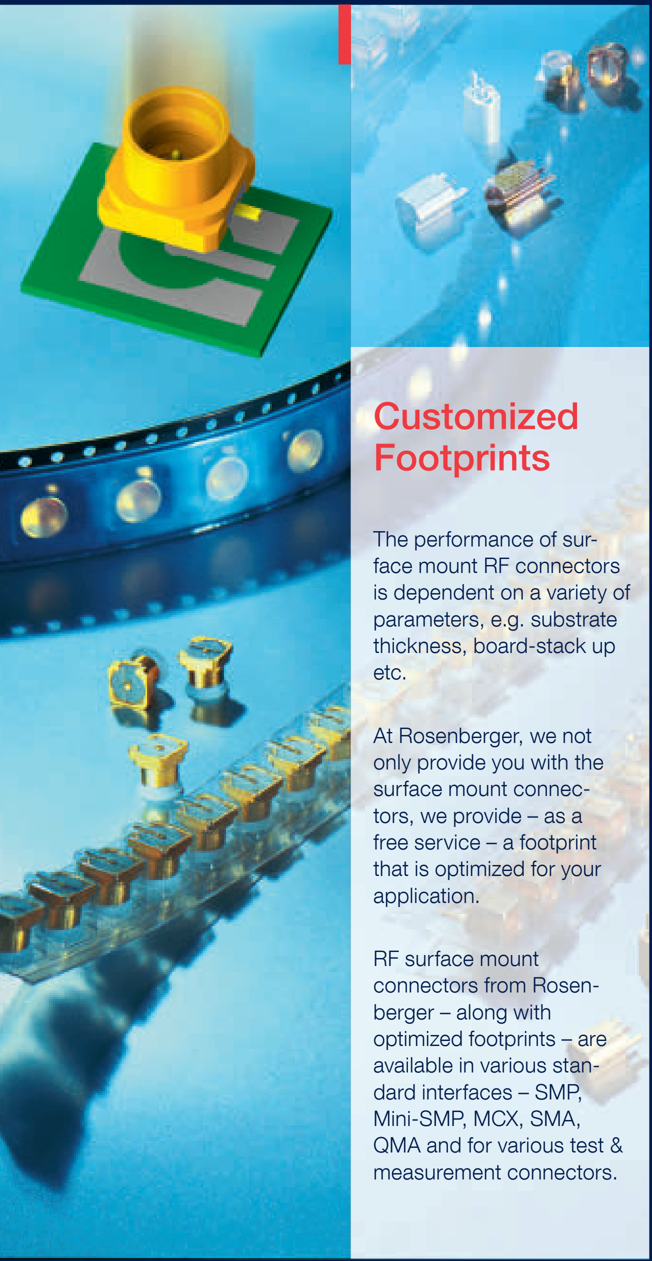
API Technologies Corp. announced it has received a $2 million order for its high-reliability, radar warning receiver indicator solution. The solution will be used as part of an Electronic Warfare Management System (EWMS).

Mercury Systems, Inc., a leading provider of affordable, commercially developed, open sensor processing systems and services for critical commercial, defense and intelligence applications, announced it received $4.4 million in orders from a leading defense prime contractor for advanced RF microwave tuner and intermediate frequency (IF) products for a naval signals intelligence (SIGINT) application. The orders were booked in the company's fiscal 2014 fourth quarter and are expected to be shipped by its fiscal 2015 second quarter.

PEOPLE

▲ *Diane Daegele*

Northrop Grumman Corp. announced **Diane Daegele** has been appointed vice president of business management for the Unmanned Systems division of its Aerospace Systems sector. In her new role, Daegele will be responsible for the financial and business administration activities for Unmanned Systems and its programs. Daegele joined the company in 1985 and has held numerous positions in business management and business development in such areas as advanced technology programs, national systems and TRW Ventures.



Around the **Circuit**

Micron Technology Inc. announced that **Stephen Pawlowski** has been named as vice president of Advanced Computing Solutions. Pawlowski will be responsible for helping Micron's computer and networking business unit further define and develop value-added memory solutions across enterprise and high-performance computing markets. Pawlowski joins Micron following a 31-year career at Intel Corp. where he most recently served as senior fellow. During his career at Intel, Pawlowski also served as chief technology officer of the Data Center and Connected Systems Group and general manager of the Architecture and Pathfinding Group.

Indium Corp. announced that **Brian Reid** has joined the company as vice president of operations. Reid is responsible for managing operations to achieve superior productivity, efficiency, quality, capability and delivery. Reid has more than 14 years of international manufacturing experience, including the creation and implementation of strategic plans, facility and capital management, and site master planning. Most recently, he served as vice president of operations for Norwich Pharmaceuticals in Norwich, N.Y.

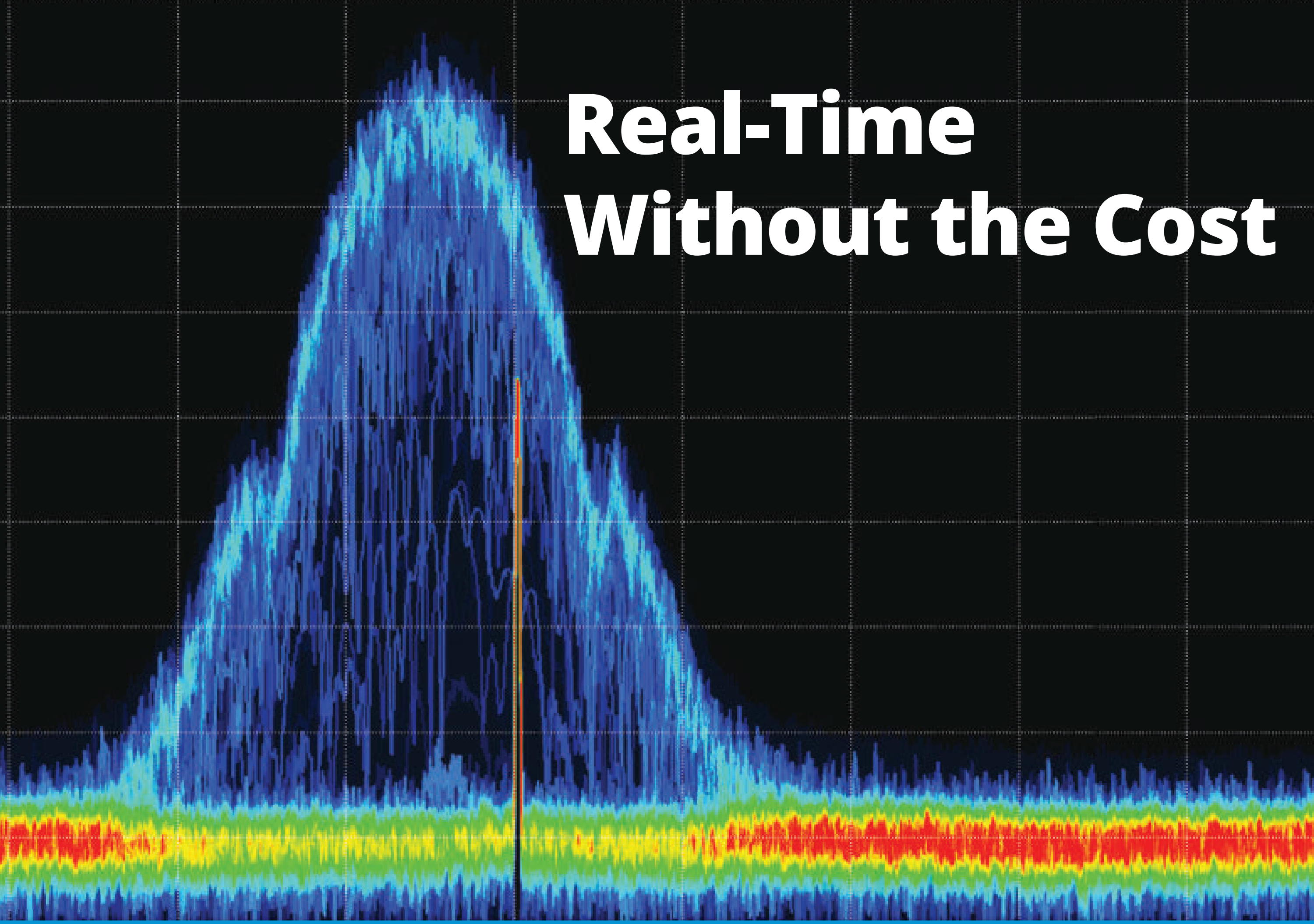
▲ *Brian Reid*

Cory Allen has joined **Signal Hound** as marketing director to develop web-based marketing structure and strategy for the company's growing customer base. Allen comes with a wealth of experience in website and creative development. Most recently, Allen worked with several regional and national companies, including The Yoshida Group and Columbia Ultimate. In various marketing and creative services roles, Allen provided website design and development, social media marketing and market analysis.

▲ *Peter Riedel*

Peter Riedel has joined the **Rohde & Schwarz** executive board, succeeding Gerhard Geier who has retired. A company veteran of nearly 25 years, Riedel's most recent position was head of the Radiomonitoring and Radiolocation Division. As the third member of the executive board, alongside president and CEO Manfred Fleischmann and president and COO Christian Leicher, Riedel will be responsible for the four operational divisions: test and measurement, broadcasting, secure communications, and radiomonitoring and radiolocation. He will also be responsible for the Rohde & Schwarz subsidiary R&S Asia.

Leader Tech, a U.S. manufacturer of EMI shielding products, announced the appointment of **Ike Wintin** as the company's new southeast regional sales manager. In his new position, Ike is responsible for managing all sales efforts for the southeastern U.S. region. Over his five-year tenure with Leader Tech, Ike has been a valued part of the




BB60C 9 kHz to 6 GHz
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sales team. He has held several positions in inside sales, estimating, and as international sales manager. Ike has earned an outstanding reputation as a dependable, loyal, responsive and productive sales manager in both the metals and electronics industries.

REP APPOINTMENTS

Anritsu Co. has expanded **RFMW**'s distribution territory for coaxial connectors and coaxial components. Along with the United States, the specialty electronics distribution company will now also market and sell Anritsu connectors and components in Canada, Mexico, as well as Central and South America. Anritsu is a leader in the design and production of precision microwave components, and holds numerous connector design patents.

Custom MMIC, a developer of performance driven monolithic microwave integrated circuits (MMIC), announced the appointment of **TECH-INTER** as its new European technical sales representative. TECH-INTER will cover France, Belgium, Netherlands, Luxembourg and Germany.

MITEQ Inc. announced the appointment of **Instrumental Tech** as the company's non-exclusive sales representative in Argentina. Instrumental Tech will represent MITEQ's Component and SATCOM divisions. The company also announced the appointment of **Vermont Representacoes** as the company's non-exclusive sales representative in Brazil. Vermont Representacoes will represent MITEQ's Component and SATCOM divisions.

Rosenberger of North America LLC announced **R-Mor** cable assemblies for test and measurement applications. These high performance microwave cable assemblies offer very low loss and high phase stability during flexure. R-Mor includes a wide range of available connectors, 2.92 mm/K, 3.5, Precision N, SMA and 2.4 mm, as well as a highly flexible armor, ensuring highly repeatable measurements. Rosenberger's R-mor cables are available through RFMW distribution in standard lengths of 18", 24", 36" and 48".

XMA Corp. announced the appointment of **CK Associates** as its exclusive sales representatives for the southwestern region of the U.S. This territory includes Ariz., N.M., Nev. (Clark County) and southern Calif. (which includes Los Angeles, Orange County, San Diego and Imperial Counties), as well as Baja California (Maquiladoras).

WEBSITE

Tango Wave announced their new website (www.tangowave.com) is up and running. Tango Wave will also be participating in the IBC2014 (International Broadcasting Convention) conference and exhibition in Amsterdam. Tango Wave is a manufacturer of high-power, high-linearity outdoor unit traveling wave tube amplifiers and subsystems designed for direct-to-home, global up-linking, satellite news gathering, broadcasting, voice/data, mobile up-linking and maritime applications.

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	RUDAT-6000-30	0 – 30 dB	±0.75 dB	0.25 dB	✓	-	✓	$395
NEW	RCDAT-6000-30	0 – 30 dB	±0.75 dB	0.25 dB	✓	✓	-	$495
	RUDAT-6000-60	0 – 60 dB	±1.00 dB	0.25 dB	✓	-	✓	$625
	RUDAT-6000-90	0 – 90 dB	±1.70 dB	0.25 dB	✓	-	✓	$695
NEW	RCDAT-6000-60	0 – 60 dB	±0.30 dB	0.25 dB	✓	✓	-	$725
NEW	RCDAT-6000-90	0 – 90 dB	±0.40 dB	0.25 dB	✓	✓	-	$795

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523 Rev A

WELCOME TO EUROPEAN MICROWAVE WEEK 2014

Roberto Sorrentino
General Chairman, EuMW 2014
Ivar Bazzy
President, Horizon House Publications

For complete coverage of the EuMW conference, event news, exhibitor product information and special reports from the editors of *Microwave Journal*, visit our online show daily at www.mwjournal.com/eumw2014.

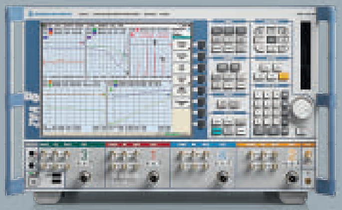
Benvenuto and welcome to the Eternal City of Rome where all roads, train tracks, bus routes and flight paths lead to the Fiera di Roma, which will play host to the 17th European Microwave Week from 5 to 10 October. During the week the three conferences: the 44th European Microwave Conference (EuMC), the 9th European Microwave Integrated Circuits Conference (EuMIC) and the 11th European Radar Conference (EuRAD), together with the European Microwave Exhibition and affiliated workshops and short courses will be the focus of the global RF and microwave industry.

The motto for 2014 is *Connecting the Future*, which relates to the connection between Rome's cultural heritage and the future of modern technology. It epitomizes EuMW's balance of the established and trusted with the groundbreaking and innovative, and illustrates a commitment to building firm foundations that promote and encourage the development of new technology and drive the industry forward.

To connect industry with academia, the Welcome Reception on Tuesday evening provides an opportunity for networking and encourages interaction between delegates and industry in a relaxed and convivial atmosphere. On Wednesday evening the Gala Dinner will offer a special blend of art, history, music and Italian food in the historical Palazzo Brancaccio, preceded by a vocal music concert in the magnificent ancient Basilica di San Martino ai Monti, featuring the famous Italian soprano Gemma Bertagnolli. A strong calendar of social events allows attendees to mix business and pleasure throughout the week.

With a city rich in historical landmarks such as the Colosseum, the Trevi Fountain and the Spanish Steps, Rome is the perfect setting for European Microwave Week to celebrate significant achievements in the history of technological innovation. Professor O. Bucci will kick off the week with his keynote speech commemorating the 150th anniversary of James C. Maxwell's theory of Electromagnetism. An EuMC Special Session will also commemorate the 50th anniversary of the famous "Black Bible," by Matthaei, Young and Jones. Lead author Professor George Matthaei will provide his presentation via skype, offering insight into the historical aspects of the book, its contributors and its impact on the entire microwave industry.

While having Europe at its heart, EuMW



embodies and embraces the global RF and microwave industry. As an example, in the framework of the fruitful collaboration established in 2007 between EuMA and the Asia Pacific Microwave Conference (APMC), a Special Session on APMC will feature three presentations highlighting recent achievements in microwave technology in this region.

The well-established Women in Engineering event, co-sponsored by the IEEE MTT-Society, will present "Exploiting Microwaves for Preservation and Enhancement of Cultural Heritages and Archaeological Sites," and will fittingly end with a guided tour of the archaeological site of Ostia Antica.

The Roman Forum is another famous feature of the city and for one day EuMW will put the spotlight on its own Forum – the Defence, Security and Space Forum. Now a major feature of EuMW, this Forum will take place on Wednesday 8th October, with executives representing industry, academia, the military and space agencies. It will encompass the EuRAD Opening Session for the third year running and conclude with the Executive Forum. More information can be found on page 78.

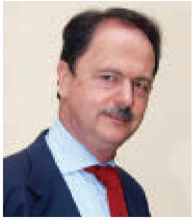
In addition to *Connecting the Future*, EuMW 2014 will play a major role in connecting visitors and delegates with the industry that puts the theory into practice and products in the marketplace. The European Microwave Exhibition from 7 to 9 October offers the opportunity to get close-up and hands-on with the latest innovations from leading RF and microwave companies across the globe. Hall 9 will be filled to capacity with over 240 exhibiting companies taking up close to 8,000 square meters of gross space.

Engineers need practical solutions. The European Microwave Week Microwave Application Seminars (MicroApps) that will take place in the MicroApps Auditorium in Hall 9 for the entire three days of the exhibition offers a platform for education and discussion. The Exhibition Hall will also be the home of the conference Poster Sessions and Coffee Breaks which will feature the Publisher's Corner and the ever popular Cyber Café.

Connecting the Future is particularly relevant for the youngest attendees, which is why EuMW continues to encourage student participation by offering two student competitions for master and doctoral students. The Student Challenge is a poster competition where groups of students develop new ideas based on papers presented at the conference. The Student Design Competition is a design and measurement contest where the students present the performance of prototypes they have designed and built. Also, after its successful introduction in Nuremberg in 2013, the Industrial Career Platform offers the opportunity for companies to meet students and young engineers looking for a career in the RF and microwave sector.

As you can imagine, preparing and hosting EuMW requires a major effort, from paper submission and review, to the on-site organization at the venue. On behalf of the Local Organizing Committee we would like to thank the Technical Programme Committees of the three conferences along with the reviewers who worked tirelessly to shape the conference programmes. We would like to acknowledge the EuMA Board for their continued advice and guidance and thank the Horizon House personnel assigned to EuMW for their indispensable expertise and support in organizing this major event. Recognition should also go to the organizers of workshops, special sessions and student events as well as the significant financial and in-kind sponsorship of many industrial companies and organizations.

We hope that the comprehensive and varied, yet focused programme of events will lead YOU to Rome in October, and we look forward to seeing you there. ■

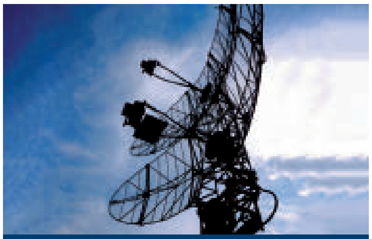

Roberto Sorrentino


Ivar Bazzy

United Monolithic
Semiconductors

RF and mm-wave
Die and packaged solutions


Space


Defense


Automotive


Telecom

Product solutions

Catalogue and specific developments

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- Very Low Noise Amplifiers
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Foundry solutions

GaAs and GaN technology offer

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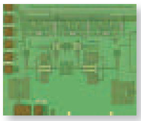
- Dedicated runs
- Known good dies
- Packaging services

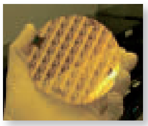
Technology Platform

Semiconductors

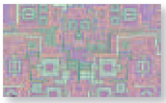
GaAs



GaN



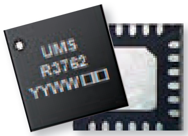
SiGe



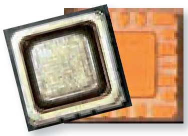
Plastic & hermetic packaging

Flange

QFN



Ceramic



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Richard Mumford
Microwave Journal *International Editor*

Rome was not built in a day and the same goes for European Microwave Week. Over many years EuMW has evolved into the premier RF and microwave event in Europe and this year every effort has been made to tap into its history, build upon its strengths and drive the event forward.

Bringing industry, academia and commerce together, EuMW 2014 is a six-day event that includes three cutting edge conferences and one exciting trade and technology exhibition featuring leading players from across the globe.

The response to the Call for Papers has been impressive with 1,124 papers, plus 32 workshop and short course proposals submitted to the three conferences from close to 60 countries. The result is an outstanding Technical Programme with 109 technical sessions, 518 oral papers and 144 posters; plus special, focused and panel sessions covering a very broad range of conventional and emerging technical subjects.

The week's global reach and influence is illustrated by the fact that the opening and closing plenary sessions of each conference will feature keynote lectures delivered by internationally renowned leaders in their respective fields. Allied to the European Microwave Exhibition, exhibitor workshops and seminars on a variety of topics have also been organized.

EuMW 2014 is expected to attract approximately 1,600 conference delegates, 4,000 attendees and more than 240 exhibitors.

The theme for 2014 is *Connecting the Future* and the EuMW Welcome Reception will continue to connect industry and academia by providing a conducive platform for networking and interaction. On Tuesday 7 October the reception will be held in Hall 8 of Fiera di Roma. The evening will begin with a cocktail reception at 18:30, where guests will be addressed by the 2014 EuMW Chairmen. Guests will also hear remarks from the 2015 EuMW Chairman for Paris and Platinum Sponsor Keysight Technologies, and enjoy a three course buffet dinner.

The social aspect of EuMW will certainly be active throughout the week. The Gala Dinner scheduled for Wednesday evening will offer a special blend of art, history, music and Italian food. Although convivial interaction is essential to a successful event, the main aim of course, is to ensure that attendees have a productive and informative week. To help visitors achieve these aims the following quick reference guide is designed to complement the Conference Programme and Exhibition Show Guide, where you will find more detailed information.

THE CONFERENCES

There are three focused conferences throughout the week with their own dedicated time slots.

- **The 9th European Microwave Integrated Circuits Conference** (EuMIC) Monday 6 and Tuesday 7 October
- **The 44th European Microwave Conference** (EuMC) Monday 6 to Thursday 9 October
- **The 10th European Radar Conference** (EuRAD) Wednesday 8 to Friday 10 October
- Workshops and Short Courses – from 5 October
- In addition, the **Defence, Security and Space Forum** will take place on Wednesday 8 October

The conferences cover a wide range of subject areas including: microwave, millimetre-wave and submillimetre-wave systems; antennas and propagation; wireless technologies; telecommunication (RF, microwave and optical); ICs, semiconductor materials and packaging; radar architectures, systems and subsystems; and sensors and remote systems.

Registration, sponsored by Rohde & Schwarz, opened online 2nd June 2014 and remains open up to and during the event until 10th October. There will be onsite registration from Saturday 4th October from 16:00 to 19:00 and from 08:00 each morning from Sunday 5th October to Friday 10th October.

The registration area will be located in Conference Hall 10 (Centro Convegni). Attendees who have pre-registered should bring their badge barcode and confirmation to the Fast Track desk onsite to have their barcode scanned and badge printed. For those who have not pre-registered there will be onsite registration terminals located within the registration area, where delegates can enter their details and either pay immediately by credit or debit card or at the cashier desk which provides a printed receipt.

Once in possession of their badges, delegates can collect their delegate bags, sponsored by Copper Mountain Technologies, Infineon and Selex ES. The bags will include a USB stick containing the conference proceedings.

THE EUROPEAN MICROWAVE CONFERENCE

The technical programme extends from Monday to Thursday and features about 80 oral sessions, including focused sessions on hot topics, and three poster sessions, some of them joint with the other conferences. Moreover, 20 satellite workshops distributed between Sunday, Monday and Friday will allow for a comprehensive and strong interactive discussion on specific topics of broad interest.

The conference will formally start with the Opening Session on Tuesday, where two keynote speeches will be delivered by distinguished keynote speakers: Prof. O. Bucci from the University of Naples "Federico II" will elucidate the evolution of Maxwell's theory of electromagnetic fields, and Philipp Schierstaedt from Infineon will speak on, "RF and RF-Power Devices for Communications and Active Safety Systems."

As part of the collaboration between the European Microwave Association and the Asia Pacific Microwave Conference (APMC), a special session has been organized where three distinguished invited speakers will consider technological advancements in the Asia Pacific region.

The Closing Session will include a panel discussion promoted by the European Radio and Microwave Interest Group (EuRaMIG) on: "The Impact on Research Policy and Technical Developments in Europe Due to the Internet-of-Things and Other Technologies Within Horizon 2020." Finally, the award ceremony for the EuMC Microwave Prize, the two EuMC Young Engineers Prizes, the Student Challenge Prize, and the Student Design Competition Prizes will close the conference.


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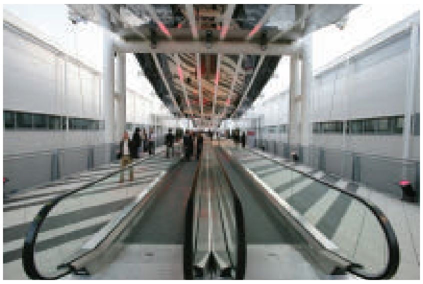
EuMW 2014
CONNECTING THE FUTURE



THE EUROPEAN MICROWAVE INTEGRATED CIRCUITS CONFERENCE

The former GAAS® conference began in Rome in 1990. In 2014, its successor – EuMIC – will celebrate its 9th edition. Jointly organized by GAAS® and EuMA, EuMIC remains the largest scientific event in Europe related to RF microelectronics. With about 170 papers submitted from authors all over the world, the conference is focused on high frequency applications of composite semiconductors, with the emphasis this year on space applications, from active device technologies to monolithic integration techniques.

Modelling topics featured will include device and system, small-signal and large-signal characterization, setups and modelling approaches, and THz applications. In the technology sector, papers on wide-bandgap devices and technologies, as well as devices for microwave photonics and space-aspects of IC technologies have become a significant part of the conference programme. Additional topics will include circuit design and applications; millimetre-wave and sub-millimetre-wave devices and circuits; mixed-signal, tunable and reconfigurable ICs; and integrated receivers and transmitters.

Two eminent and internationally recognised plenary keynote speakers launch the opening session: Prof. Piergiorgio Picozza, of the University of Rome Tor Vergata will cover "Microwaves and the Mysteries of the Universe," and Luigi Pasquali, CEO of Telespazio will consider "Microwave Sensors and Technologies for Earth Observation."

The closing session will include the traditional Foundry Session and two presentations: Franco Ongaro, technical director, ESA/ESTEC, will discuss "Microwave Technologies for Space in Europe," and Ron Reedy, CTO of Peregrine Semiconductor, will stress a facet of "CMOS Integration: From Technology Breakthroughs to System Applications." During the Closing Session, the Best Contributed Paper to EuMIC 2014 and the EuMIC Young Engineer Award will be presented along with three GAAS® PhD Student Fellowships.

THE EUROPEAN RADAR CONFERENCE

EuRAD covers all relevant aspects of modern radar technology including components, subsystems, architectures, applications and signal processing. This year 190 papers were submitted, representing 18 percent of all papers submitted to EuMW. In addition, renown researchers in the radar community have organized focused sessions on hot topics such as "Advances in Passive Radar Systems, Clutter Modelling and Interference Suppression in Bistatic Radar Systems" and "Advanced Tomographic SAR Imaging: Processing Techniques and Applications."

Two special sessions will review: "110 Years of Radar Developments in Europe After Hulsmeyer's Telemobiloskop" and "Autonomous Driving-Status-Quo and the Next Generation of Automotive Radar."

The opening session, which forms part of the Defence, Security & Space Forum features two eminent plenary keynote speakers: Hugh Griffiths, Professor at the University College London, will consider: "The Challenge of Spectrum Engineering" and Robin Evans, Professor at the University of Melbourne, Australia, will discuss "Consumer Radar – Opportunities and Challenges."

Expert workshops will take place on Sunday and Friday covering advanced areas of radar including: compressive sensing for radar applications; noise radar: monostatic, multistatic and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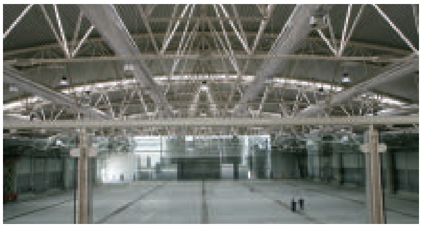


MIMO; forward radar scattering and photonics for radar systems.

THE EXHIBITION

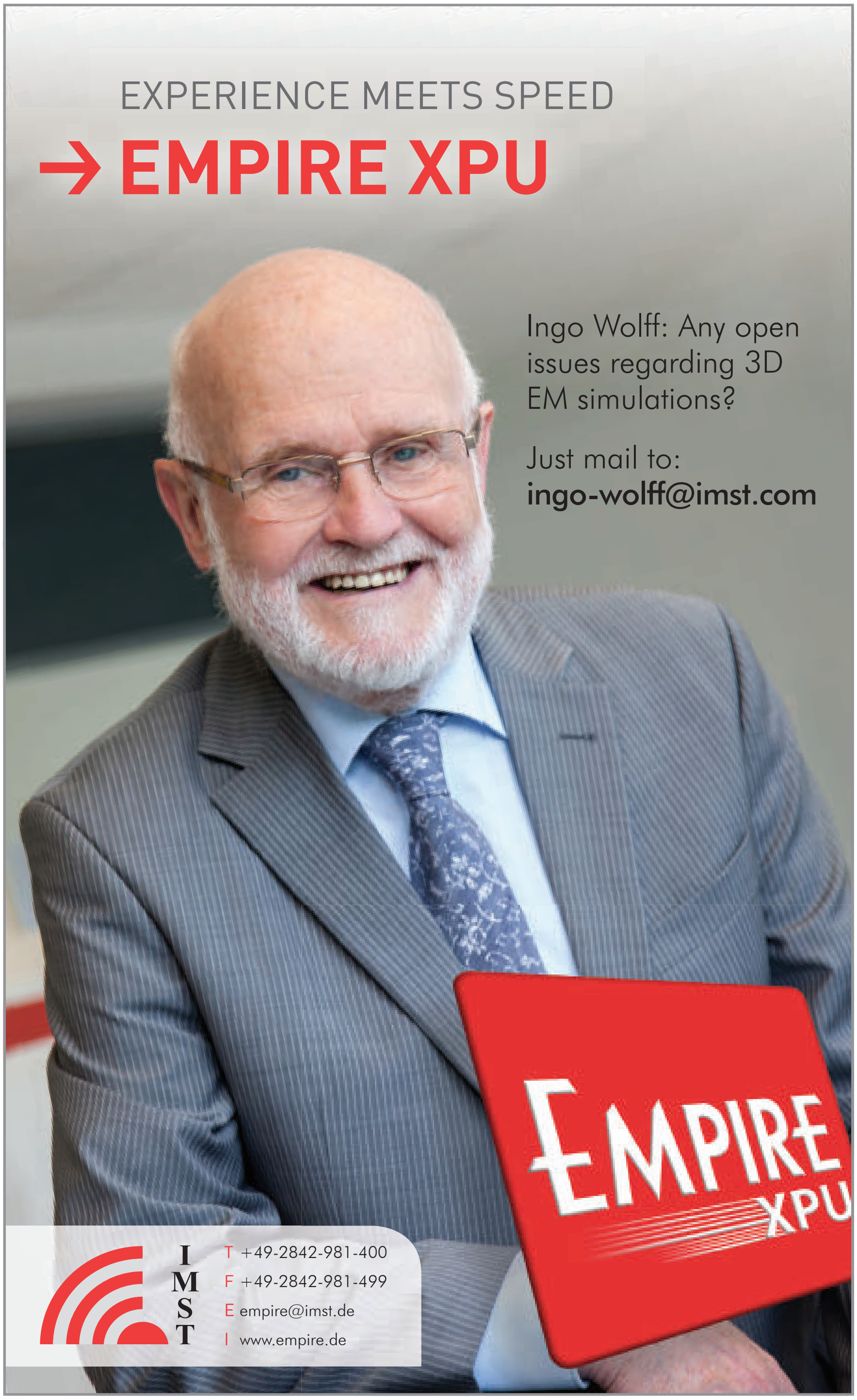
The European Microwave Exhibition, 7 to 9 October, plays a central role in promoting the products and services that are at the forefront of innovation. It is the major platform in Europe for RF and microwave manufacturers to showcase their portfolio of products and latest technology to a global audience. The exhibition offers engineers, in particular, the opportunity to discuss current projects with the experts and find solutions.

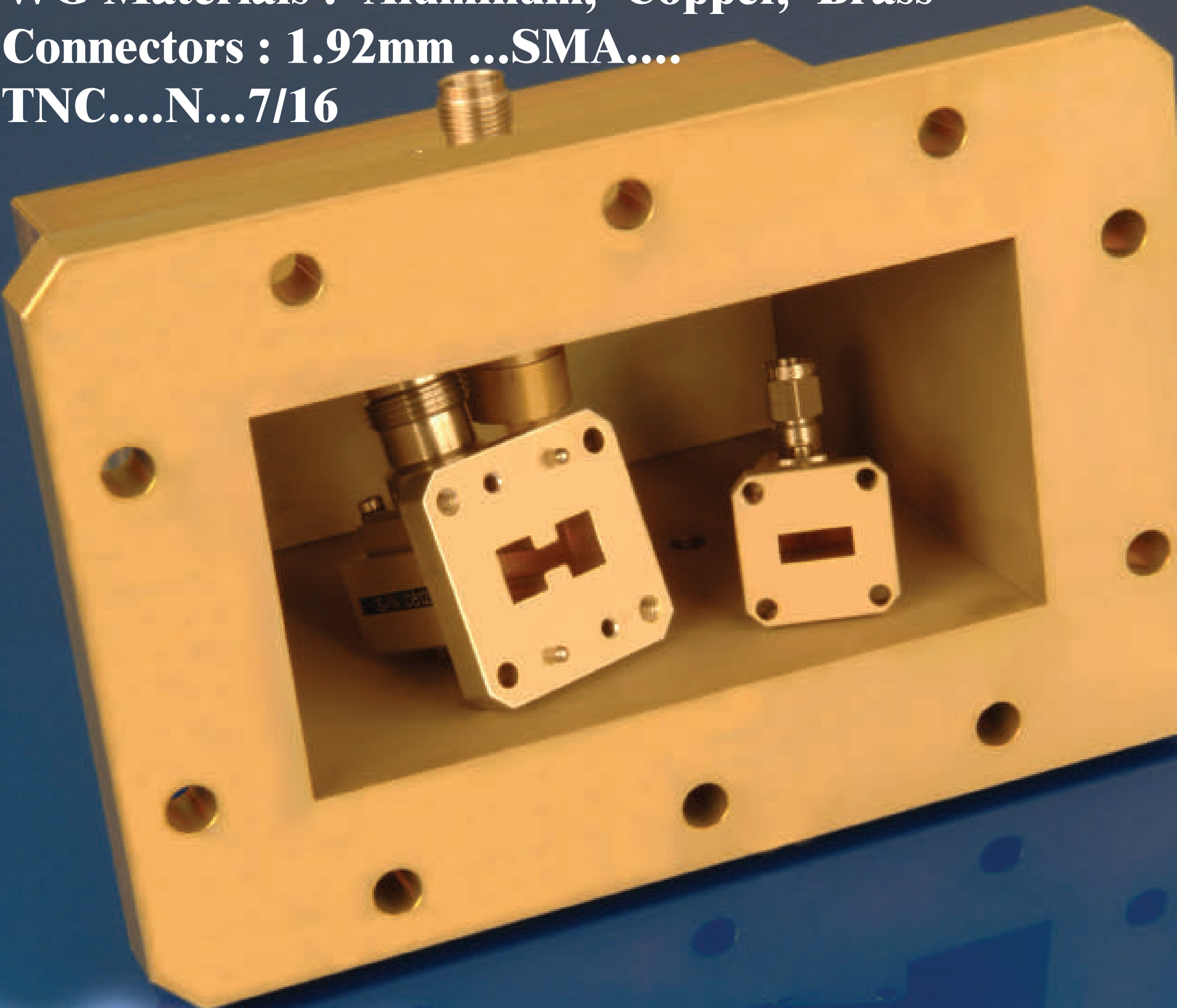
Significantly, Keysight Technologies will be exhibiting their wide range of RF and microwave test and measurement products for the first time as a new trading entity. After much anticipation, EuMW will offer visitors the chance to see, first hand, the company's new set-up, view its current activities and discover its future plans. Keysight will also be sponsoring the coffee breaks where the coffee will be served in mugs sporting the company's new logo. Alongside Keysight will be all the major manufacturers in the industry, many of which will use the exhibition to launch new products and float future concepts on the show floor.

A trend that has emerged over recent years has been the development of pavilions that provide an identity and platform for smaller companies and distributors to collectively band together and demonstrate the diversity of their country's industry. This year the number of pavilions has grown to include European representation from past, present and future EuMW host countries including: Germany, France, Holland, Italy and Spain. Demonstrations during the week is truly international – the Chinese pavilion will again be prominent, while manufacturers from the rest of Asia and the U.S. continue to be well represented. To find out which companies will be exhibiting see the latest exhibitor list, on page 189.

A number of companies will again hold the popular Exhibitor Workshops where experts in their fields will offer live and hands-on demonstrations. The educational/instructional theme will continue on the show floor of Hall 9 with European Microwave Week Microwave Application Seminars (MicroApps), which, now in its fourth year, has become a recognized event in itself. The National Instruments (NI) (formerly AWR Corp.), Rohde & Schwarz and Horizon House sponsored seminars will take place in the MicroApps Auditorium for the entire three days of the exhibition.

And there's more... The exhibition hall will also be the home of the conference Poster Sessions, Coffee Breaks and the Publisher's Corner. Once again CST is sponsoring a Cy-





ber Café located on the show floor for all delegates, exhibitors and visitors to use, with free Wi-Fi access.

EXHIBITION OPENING HOURS

Tuesday 7 October: 09:30 to 17:30 (followed by the Welcome Reception)
Wednesday 8 October: 09:30 – 17:30
Thursday 9 October: 09:30 – 16:30

GETTING TO THE FIERA DI ROMA

Fiera di Roma is located less than 5 kilometres from the Leonardo da Vinci (Fiumicino) Airport of Rome and visitors should use the North Entrance.

By Car

From the GRA (Rome's orbital) take Exit 30 toward Fiumicino, then follow the signs for Fiera di Roma where there are 5,000 parking spaces.

By Rail

Fiera di Roma is connected to the Rome Tiburtina, Tuscolana, Ostiense and Trastevere stations by the FL1 regional train. FL1 trains run every 15 minutes (30 minutes on Sundays and Holidays).

By EuMW Shuttle Buses

To enable easy access to the venue three free shuttle bus routes have been organised. Route (A) Shuttle buses connecting the Fiera di Roma station of FL1 train to the Fiera di Roma North entrance. Route (B) Shuttle buses from Magliana Station of the Metro B line to Fiera di Roma. Route (C) Shuttle buses from the Holiday Inn Eur Parco De Medici (Headquarter Hotel) and hotels located in the vicinity of Parco dei Medici (Sheraton Golf, Marriott Rome Park Hotel and Ibis Roma Fiera) to the FL1 station Muratella. For more information visit: www.eumweek.com/conferences/How-to-Get-Here.html#sthash.sJd1bVQ4.dpuf.

HOTEL RESERVATIONS

Horizon House has teamed up with Hotelzon to offer a wide range of accommodations at competitive rates. To make a booking simply visit Hotelzon's booking page at www.hotelzon.com/en/uk/events-eumw or email sally.garland@hotelzon.co.uk.

SHOPPING & SIGHTSEEING

Rome is a beautiful and exciting city, known for its history, cuisine and fashion. Whether you are looking to relax or sightsee, Rome has so much to offer. There are the famous tourist attractions such as The Vatican and St. Peter's Square, the Colosseum, Trevi Fountain and the Spanish Steps, as well as many museums and galleries.

Italy's capital is also a great place for shopping. The most popular shopping areas include: Piazza di Spagna (Spanish Steps, Via dei Condotti), Via del Corso, Trastevere (located just over the River Tiber), Viale Marconi and Porta Portese, and Piazza Navona (Via del Governo Vecchio).

There are various tours and excursions organized as part of the EuMW Social Events & Partner Programme. Visit www.rome.info for more information. ■

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THE 2014 EUMW DEFENCE, SECURITY AND SPACE FORUM

Richard Mumford
Microwave Journal *International Editor*

A one-day Forum on Wednesday 8 October, addressing the application of RF integrated systems to defence and security infrastructure.

Room Flavia

Fiera di Roma Conference & Exhibition Centre

The defence and security of individuals, property, transportation systems and borders is fundamental to national and international stability. Threats are ever present and ever changing – they can come from land, sea or air and can be enacted by armies or a single terrorist. Similarly, the methods and technology that is being developed to combat such threats must adapt and evolve too.

Recently, the vital role of space for civil security, emergency response and crisis management has matured. Space based systems are key enabling technologies for data transmission, observation and positioning, affording them a vital role in the effective implementation of defence and security systems.

Consequently, as the title suggests, the space sector will be a major focus of the 2014 EuMW Defence, Security and Space Forum. Following its established format the Forum will feature executives from industry, academia, the military and from space agencies. It will be held in combination with the opening of EuRAD and will conclude with a round-table discussion.

This year there will be special emphasis on how RF integrated systems can be designed and deployed into structures such as buildings, plants, dams, airplanes, airships, UAV and spacecraft that will serve as critical infrastructure protection and resilience.

THE FORUM FORMAT

To follow is a brief outline of each session. A full listing of the presentations at the time of going to press can be found on pages 82 and 83.

The Forum begins with the "Microwave Journal Industry Panel Session" (09:00 - 10:40), which will offer an industry perspective on the key issues facing the defence, security and space sector. In accordance with the theme for 2014, the panel will address: "Defence and Security Infrastructure." The morning will conclude with the "EuRAD Opening Session" (11:20 - 13:00).

The "Strategy Analytics Lunch and Learn" session will add a further dimension by offering a market analysis perspective, illustrating the status, development and potential of the market.

The early afternoon session (14:20 - 16:00) will consider "Integrated RF Solutions and its Enabling and Disruptive Technologies on

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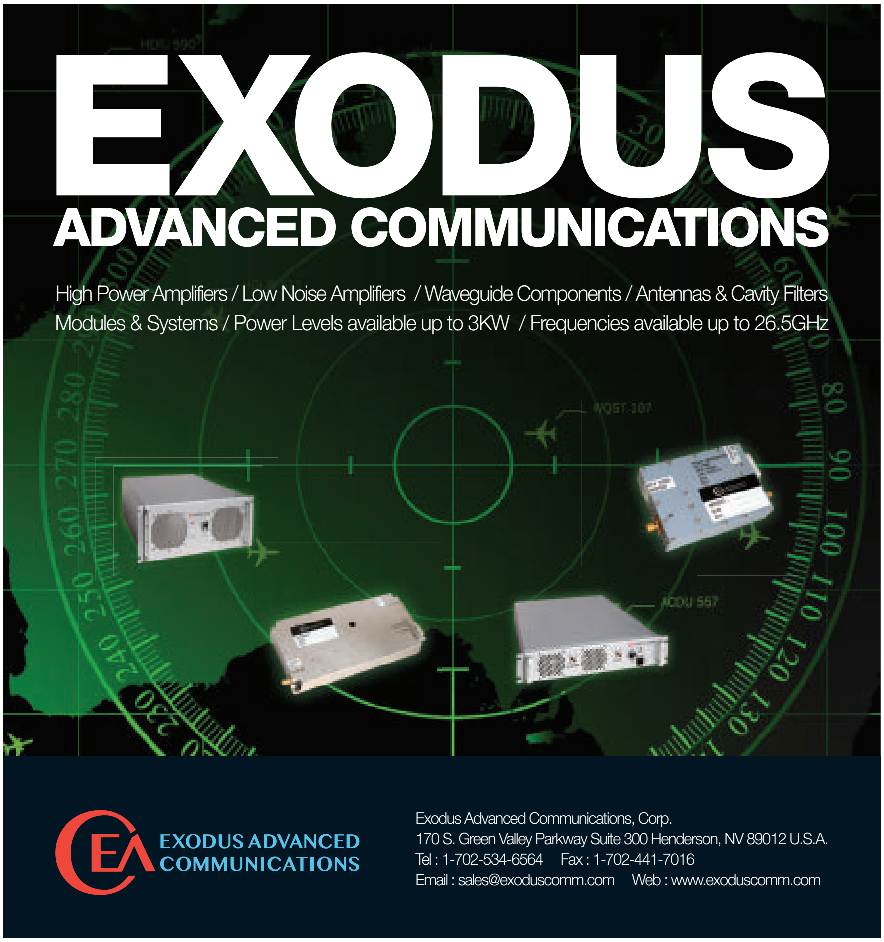

Critical Infrastructures and Civil Protection." It will feature speakers from industry and academia who will consider RF solutions and systems that contribute to civil protection, the protection of our critical infrastructures and disaster relief. The session will conclude with an open forum discussion with all speakers.

Rounding off the technical sessions the "EuMW Defence, Security & Space Executive Forum" (16:40 - 18:20) will feature two executives from space industry and governmental institutions who will proffer their views on defence and space systems for security. They will be complemented by three pitch presentations.

The day's proceedings will conclude with a cocktail reception (18:20 - 19:00) that will afford delegates the opportunity to network and discuss the issues raised throughout the forum in an informal setting.

REGISTRATION & UPDATES

Registration fees are €10 for those who have registered for a conference and €50 for those not registered for a conference. Register online at www.eumweek.com

As information is formalised, the Conference Special Events selection of the EuMW website will give details of the speakers for all sessions and will be updated on a regular basis. ■


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The 2014 Defence, Security and Space Forum

At European Microwave Week

Wednesday 8 October

**A one-day Forum addressing the application of
RF integrated systems to defence & security infrastructure**

Programme:

09:00 - 10:40 *Microwave Journal* Industry Panel Session: Defence and Security Infrastructure

- Bringing Commercial Manufacturing Practices to Defence Electronics
  Doug Carlson, MACOM, representing Richardson RFPD/Arrow RF & Power
- Going Vertical to Meet the Demands of Space
  Anthony Sweeney, Mercury Systems Inc.
- The Bandwidth Revolution: How Off the Shelf Converter Technology is Changing Electronic Warfare
  Jin Bains, National Instruments
- Defence Systems Take Flight with Intelligent RF Integration
  Duncan Pilgrim, Peregrine Semiconductor
- The State of The Art in Personnel Screening with mmWave Technology for Security Checkpoints – *Dr. Sherif Ahmed, Rohde & Schwarz*

11:20 - 13:00 EuRAD Opening Session

13:10 - 14:10 Lunch & Learn, Market Watch

- Defence Technology Strategies for Critical Infrastructure Protection
  Asif Anwar, Strategy Analytics

14:20 - 16:00 Integrated RF Solutions and its Enabling and Disruptive Technologies on Critical Infrastructures and Civil Protection

- The Domino Effects in Critical Infrastructures – *Alfonso Farina, Selex ES*
- Civil Protection, Protection of Critical Infrastructures, Disaster Relief:
  Vertical Applications over a Common Architecture with Heterogeneous Communications
  Giovanni Guidotti, Selex ES

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Register at eumweek.com

EuMW 2014
EUROPEAN MICROWAVE WEEK
ROME, ITALY
5-10 OCTOBER 2014

Room Flavia, Fiera di Roma Conference & Exhibition Centre

- Threats and Countermeasures in the Homeland Security Scenario
  Giorgio Franceschetti, University of Naples
- Security at European Institutional Level – *Cristina Leone, Finmeccanica*
- Emergency and Disaster Wideband Communication involving Satellites, Helicopters and Ground Mobile Systems – *Edgar Lemos Cid, University of Vigo*
- Monitoring of Buildings, Bridges, Houses and Monuments by Shelf Sensors and Radio Frequency (RF) Energy and Transmission – *Bruno and Sergio Pereira, Universidade de Averio*
- Improving Performance of Bio-radars for Remote Heartbeat and Breathing Detection by using Cyclostationary Features – *Daniel Malafia, Universidade de Aveiro*

16:40 - 18:20 EuMW Defence, Security & Space Executive Forum

- *Col. Walter Villadei, Italian Air Force, ItAF Space Policy Office* and *Dr. Giancarlo Grasso, Finmeccanica*, will proffer views on defence and space systems for security.
- Joint Applications of Airborne and Spaceborne Radars – *Rudolf Zahn, Airbus Defence and Space, Frank Hensler, Astrium Eads, Martin Kirscht, Cassidian*
- Instrumented Fuzes for Aero-Ballistics Diagnostics of Large-Caliber Projectiles
  Bernard Loic, ISL
- New Technologies and Innovative Payload for Space Q/V-Band Telecommunications
  Herve Leblond, Thales Alenia Space

18:20 - 19:00 Cocktail Reception

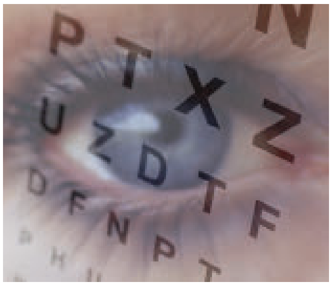
Registration fees are €10 for those who have registered for a conference and €50 for those not registered for a conference.

Details in this programme are correct at the time of going to press – updates will be posted on eumweek.com

Organized by:

Microwave Journal
Frequency Matters.

EuMA European Microwave Association



Microwaves in Europe: 20-20 Vision?

Richard Mumford
Microwave Journal *International Editor*

Horizon 2020 has evolved from vision to reality. Can it provide the focus to ensure Europe's global competitiveness and does the European RF and microwave industry have the foresight and expertise to both contribute and benefit?

Muttered only in hushed tones in the corridors of power and the boardrooms of industry in Europe, the words 'economic' and 'recovery' are tentatively being combined once again. After years of austerity, which has seen a squeeze on funding, cut backs in services and a rationalization of resources, the general consensus is that there is justification for cautious optimism.

Although it would be premature, foolhardy and amnesic to pronounce – crisis, what crisis just yet – green shoots of recovery are starting to emerge through the gloom of recession. They will need to be carefully nurtured, nourished financially and protected from the vagaries and harsh realities of the global market.

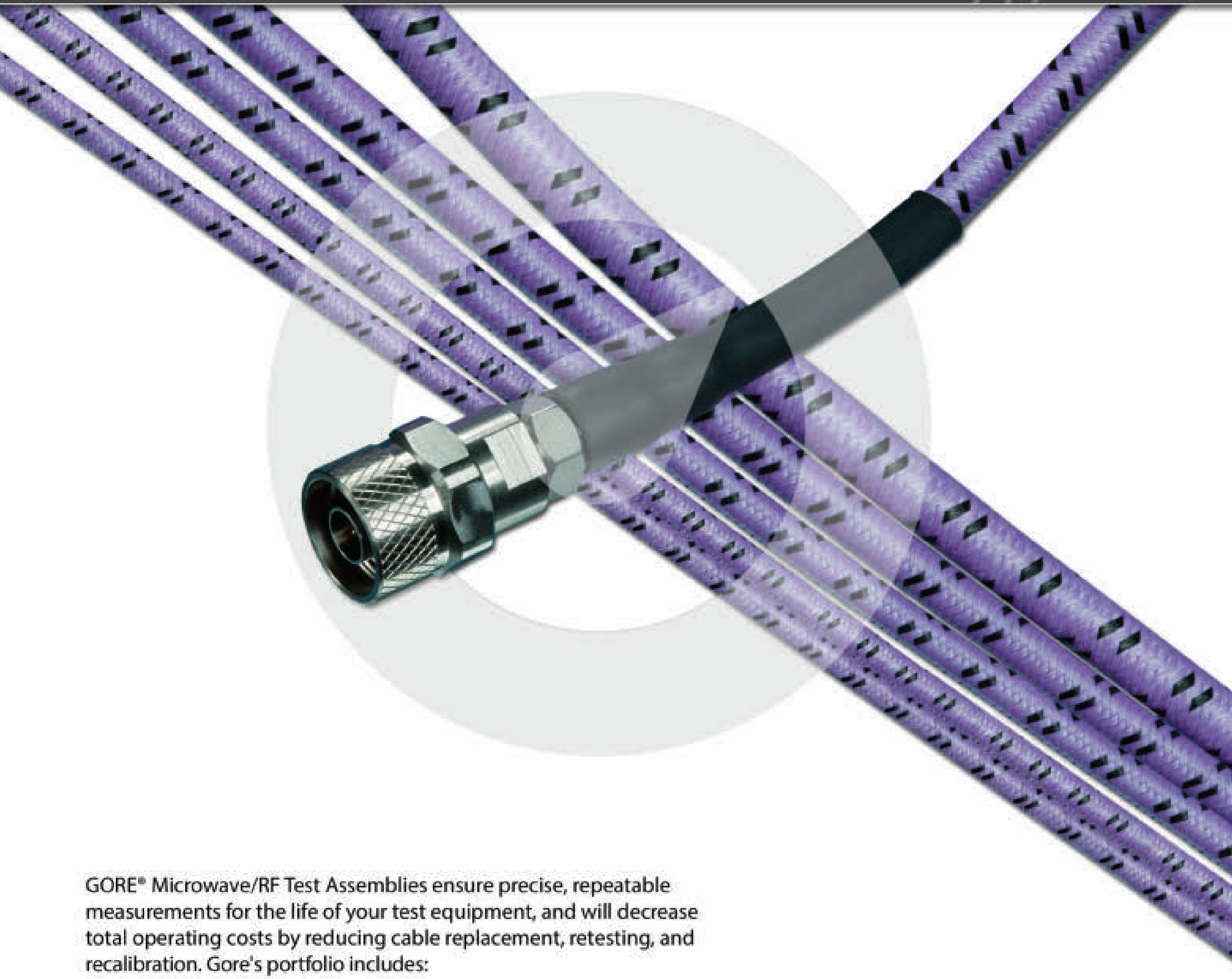
According to the latest *Innovation Union Competitiveness Report*, the EU is facing increasing world competition, in particular, at the higher end of global value chains. In 2011, more than 70 percent of the world's knowledge creation was taking place outside the EU. However, it still remains the main centre for knowledge production in the world, accounting for almost a third of the world's science and technology production and continues to be an attractive location for R&D investment.

The EU report also identifies that science and technology development in the U.S. and Asia tends to be more strategic than in the EU and more focused on transformative technologies targeted towards emerging global markets; while technologically the EU is more focused on established and traditional industries.

Encouragingly, evidence from the European Commission's *Innovation Union Scoreboard 2014* and the *Regional Innovation Scoreboard 2014* indicates that Europe is closing its innovation gap with the United States and Japan. It states that overall progress has been driven by the openness and attractiveness of the EU research system as well as business innovation collaboration – a testament to the Framework Programmes (FP) that Horizon 2020 aims to take forward.

At a global level, the scoreboard shows that South Korea, the U.S. and Japan have an innovation performance lead over the EU. However, the EU continues to outperform Australia, Canada and all BRICS (Brazil, Russia, India, China and South Africa) countries. While this lead is stable or slightly increasing, the exception is China, which is evolving at pace.

Against this background it is imperative that Europe remains competitive in order to sustain economic recovery. That means growth based on innovative products and services that can compete in global markets. Europe cannot compete on costs, so fostering commercially viable innovation is a prerequisite for growth.



In the race to prosperity, the European RF and microwave industry is in pole position, at the forefront of key technologies such as mobile communications and wireless technologies, which are sought-after commodities playing a vital role in today's society. Through its research, innovation and industrial activities, the RF and microwaves sector is addressing the issues of today, tackling technological challenges and striving to create real business opportunities.

As an entity the RF and microwave industry is extensive and far reaching, influencing a multitude of markets and impacting the everyday lives of citizens as well as the economic stability of many nations. The industry's enterprise, scale and technological trends are outlined in the RF and Microwave sector interview by EuMC 2014 Chair, Lorenzo Mariani, that appears later in this report.

Mariani points out that microwaves are a core technology for civilian, defence, and security application systems such as wireless communications, sensor networks and radar systems. He emphasises the rapid re-emergence of wireless communications, the significant role of 'adjacent technologies' such as ICT and the development of 'microwave photonics' in electronic RF based systems including radar.

...green shoots of recovery are starting to emerge...

According to EuRAD 2014 Chair Enzo Dalle Mese, the main areas of development in the radar arena are: passive, imaging, antennas and miniaturization. He also highlights the significance of the major expansion of civil applications and predicts that by taking advantage of the reduction of hardware – allied to the progress in semiconductor power devices and integrated circuit development – "radar on a chip" could become reality.

Indeed, semiconductor and IC technology are opening up new horizons. GaAs and silicon-based IC technologies are extensively used in modern systems, while emerging technologies such as wide bandgap semiconductors (GaN, SiC, etc.), InP/Antimonide CNT and Graphene-based devices are expected to become commercially available in the not too distant future. Such technology's potential to have a major impact on system performance is likely to have significant implications.

In his overview of the Semiconductors and IC sector, EuMIC 2014 Chair Franco Giannini, recognizes the significant progress in RF system miniaturization and the reduction of total power consumption, but he also sees major challenges for RF integrated circuits related to mobile communications. Giannini envisions microwave semiconductor technologies playing a key role in civil and defence systems as well as in the space environment for communications, particularly remote sensing for Earth observation and radiometry.

Europe cannot compete on costs...

The 'space environment' Giannini refers to has changed dramatically in recent years. It has become a global business and is no longer the sole preserve of a few powerful nations. With the European space industry facing increasing competition from new emerging space powers such as China and India, it is vital to ensure that it can thrive and compete in the global marketplace. That is one of the reasons why EU space research is identified by Horizon 2020 as one of Europe's 'key industrial technologies,' with Horizon 2020 dedicating €1.7 billion to space research and innovation.

Global Navigation Satellite Systems (GNSS) have come to the forefront. The launch of major projects such as the European Galileo and Chinese Beidou/Compass as well as the introduction of two new regional navigational systems – Indian Regional Navigational Satellite System and the Japanese Quasi-Zenith Satellite System – is increasing the availability of GNSS solutions.

We are also seeing the implementation of commercial off-the-shelf (COTS) GNSS solutions which can be utilized both commercially and by the military with Frost & Sullivan's *Military Global Navigation Satellite Systems Market Assessment*, finding that the market earned revenues of $1.98 billion in 2013 and estimates this to reach $2.18 billion in 2022 at a compound annual growth rate of 1.1 percent.

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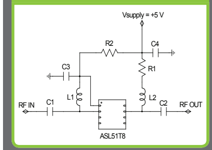

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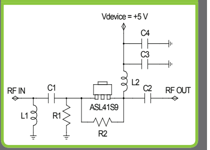

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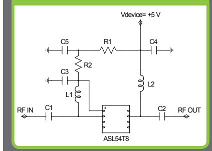

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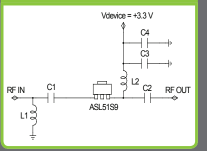

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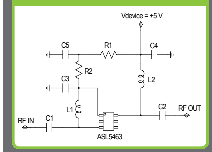

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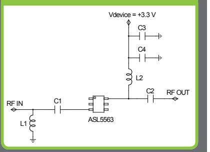

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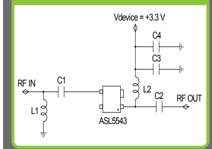


Considering defence in general, Frost & Sullivan's *Global Defence Outlook* found that defence procurement spending was $600 billion in 2013 and is expected to reach $660 billion in 2018. Command, control, communications, computers, intelligence, surveillance and reconnaissance (C4ISR) contributed the most to market revenues in 2013 due to the high demand for radars, optical sensors, sonars and secure flexible networks.

It is precisely to encourage, support and sustain such 'industry' that Horizon 2020 has been formulated to build on the Framework Programmes which have played their part in encouraging growth during a difficult trading period. After a long gestation period and much touting, the EU has put €80 billion of funding where its mouth is for Horizon 2020. The funding available over seven years (2014 to 2020) is one of the few areas of the EU's new budget to see a major increase in resources and is claimed to be around 30 percent more, in real terms, than FP7's budget.

Horizon 2020 is the financial instrument implementing the Innovation Union, which has the political backing of Europe's leaders and the Members of the European Parliament. Research is seen as an investment in the future that is at the heart of the EU's blueprint for smart, sustainable and inclusive growth and jobs. The goal is to ensure Europe produces world-class science, removes barriers to innovation and makes it easier for the public and private sectors to work together in delivering innovation.

> **...semiconductor and IC technology are opening up new horizons...**

Significant to the RF and microwave industry is that a key reform in Horizon 2020 will fund innovation as well as research and it is actively encouraging and investing in key enabling technologies such as ICT, nanotechnology, materials and production technology.

Its stated aim is to provide support at every step of the journey from 'lab to market,' offering companies – large, medium and small – numerous opportunities to take part. In addition, more money is available for testing, prototyping, demonstration and pilot type activities; for business-driven R&D; for promoting entrepreneurship and risk-taking; and for shaping demand of innovative products and services.

The next section of this report explains in more detail the structure and key initiatives of Horizon 2020 and the mechanisms in place in order to achieve those goals.

HORIZON 2020

Specific efforts have been made to cut red-tape and major simplification will be facilitated by a single set of rules. As previously mentioned, the Horizon 2020 programme is different from the seven previous framework programmes because for the first time it focuses on innovation rather than research and development and puts a greater emphasis on the deployment of technologies and their path to market.

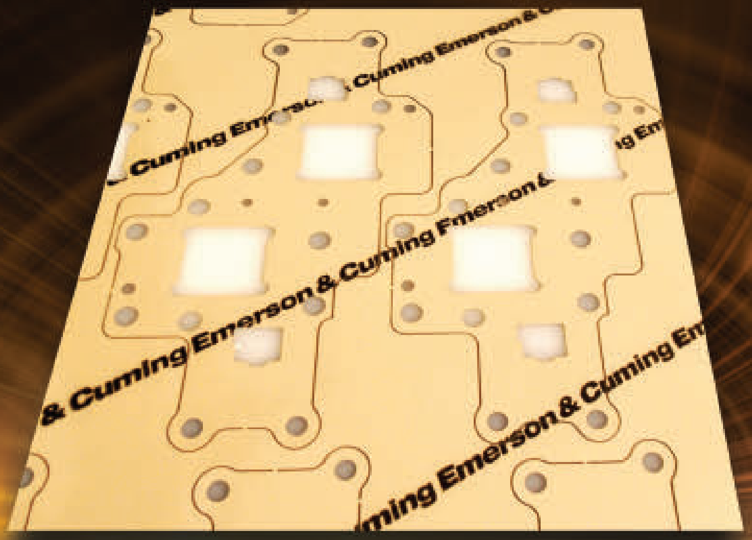
Small to medium sized enterprises (SME) are the lifeblood coursing through the veins of the European economy and they are a vital component of the RF and microwave industry.

A key ingredient of Horizon 2020 is *Innovation in SMEs*, which aims to attract more SMEs to Horizon 2020, provide support to a wider range of innovative activities and help to increase the economic impact of project results by its company-focused and market-driven approach.

Financially, *Innovation in SMEs* funds additional activities intended to support entrepreneurship, internationalization, and improved access to markets through the Competitiveness of Enterprises and Small and Medium-sized Enterprises (COSME) programme.

> **...SMEs are a vital component of the RF and microwave industry.**

COSME will run from 2014 to 2020 with a planned budget of €2.3 billion and offer two different financial instruments. Under the Loan Guarantee Facility, the COSME budget will fund guarantees and counter-guarantees for financial intermediaries to help them provide more loan and lease finances to SMEs. Via the Equity Facility for Growth, the COSME budget will also be invested



in funds that provide venture capital and mezzanine finances to expansion and growth-stage SMEs, particularly those operating across borders.

Providing SMEs access to potential markets is viewed as a priority, with COSME funding IPR SME Helpdesks for China, ASEAN and Mercosur in order to help small and medium enterprises deal with issues relating to intellectual property rights in these countries.

> **…science and engineering provide the basis for future European competitiveness and growth.**

The EUREKA and Eurostars Programmes, which regular readers of this annual report will be familiar with, are now entering the next phase, whereby the second EUREKA/Eurostars Joint Programme Initiative (2014-2020) will provide funding for market-oriented transnational collaborative R&D projects. EUREKA, like Horizon 2020, is a European platform for research focusing on turning new technologies into marketable products.

Eurostars is a European funding programme specifically dedicated to SMEs focusing on innovative technologies that pools together national resources, with the aim of strengthening integration and synchronization of national research programmes contributing to the achievement of a European Research Area. Its success under FP7 has tripled the Horizon 2020 budget for the Eurostars programme.

The Research Executive Agency (REA) is a funding body created by the European Commission to maximize the efficiency and impact of EU research and innovation programmes. REA manages the four pillars of the Horizon 2020 Framework Programme for Research and Innovation: excellent science, industrial leadership, societal challenges and cross-cutting themes. The first two are of particular interest to RF and microwave companies.

Excellent science encompasses Future and Emerging Technologies (FET), which fund collaboration between advanced multidisciplinary science and cutting-edge engineering. It is intended to help Europe grasp leadership early on in promising future technology areas and provide the basis for future European competitiveness and growth. Under Horizon 2020, FET actions have been allocated a provisional budget of €2,696 million.

Industrial Leadership will focus on space research. The motto for EU Space R&D from 2014 to 2020 under Horizon 2020 is, 'Prepare for the increasing role of space in the future and reap the benefits of space now.' The main objective of the space research initiative is to foster a cost-effective competitive and innovative space industry (including SMEs) and the research community to develop and exploit space infrastructure to meet future union policy and societal needs.

Building on the successes of FP7, Horizon 2020 will enable the European space research community to develop innovative space technologies and operational concepts – from an idea to demonstration in space – and to use space data for scientific, public, or commercial purposes. Actions will be carried out in conjunction with research activities of the Member States and the European Space Agency (ESA), aimed at building up complementarity among different players.

To achieve its goals, Horizon 2020 requires adequate and accessible funding. Therefore, the European Commission and the European Investment Bank Group (EIB) have launched a new generation of EU financial instruments and advisory services to help innovative firms access finance more easily.

> **…foster a cost-effective competitive and innovative space industry …**

Over the next seven years, it is expected that the *InnovFin – EU Finance for Innovators'* range of tailored products will make more than €24 billion in financing available for research and innovation by small, medium and large companies and promoters of research infrastructures. This financing is expected to support up to €48 billion of final R&I investments. The tailored products range from guarantees for intermediaries that lend to SMEs, to direct loans, to enterprises.

SECTOR OVERVIEWS

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that will encourage research, innovation and growth. The European RF and microwave industry is in a good position to take advantage and move forward. The activity and technological prowess of the industry will be effectively demonstrated at the 2014 European Microwave Week in Rome, Italy in October. Therefore, this report has enlisted the Chairmen of the three 2014 EuMW conferences – the European Microwave Conference (EuMC), the European Microwave Integrated Circuits (EuMIC) Conference and the European Radar Conference (EuRAD) to offer insight into key areas of development and identify future trends.

RF and Microwaves

Sector overview by Lorenzo Mariani, EuMC 2014 Chair

In the 20th century, engineering recorded major achievements – with RF and microwave technology playing a pivotal role. In the 21st century, the problem of sustaining civilization's continued advancement, while still improving the quality of life, is the immediate challenge. Old and new threats to society as a whole demand more efficient and readily available engineering solutions. RF and microwave technologies can continue to play a key role in this endeavour and the 2014 European Microwave Conference will play its part in moving technology forward.

> The 'classical microwave perimeter' is quickly expanding....

Microwaves is a core technology for civilian, defence and security application systems, such as wireless communications, sensor networks and radar systems. The rapid re-emergence of wireless communications (after G. Marconi's discovery, Nobel laureate 1909) in all facets of today's society has given microwave technology renewed prominence.

Typical enabling microwave basic technologies, devices and assemblies are: passive components and filters, tunable devices, microwave interconnects and packaging, MMICs, UWB systems, wireless power transfer and energy harvesting, biosensors, simulation and characterization tools, low phase noise equipment, high power density GaN-HEMT transistors and technical solutions for heat management.

> ...microwaves are pervasively entering into several work programmes.

The 'classical microwave perimeter' is quickly expanding, not only because of the presence of new Asian players contributing to the technology evolution, increasing the global investment in the field, but also because of the role of 'adjacent technologies' such as ICT. The increase in frequencies and bandwidths for communications is fostering a 'novel approach' in the microwave domain as is the case with fibre optics, enabling so-called 'Microwave Photonics' in electronic RF based systems including radar.

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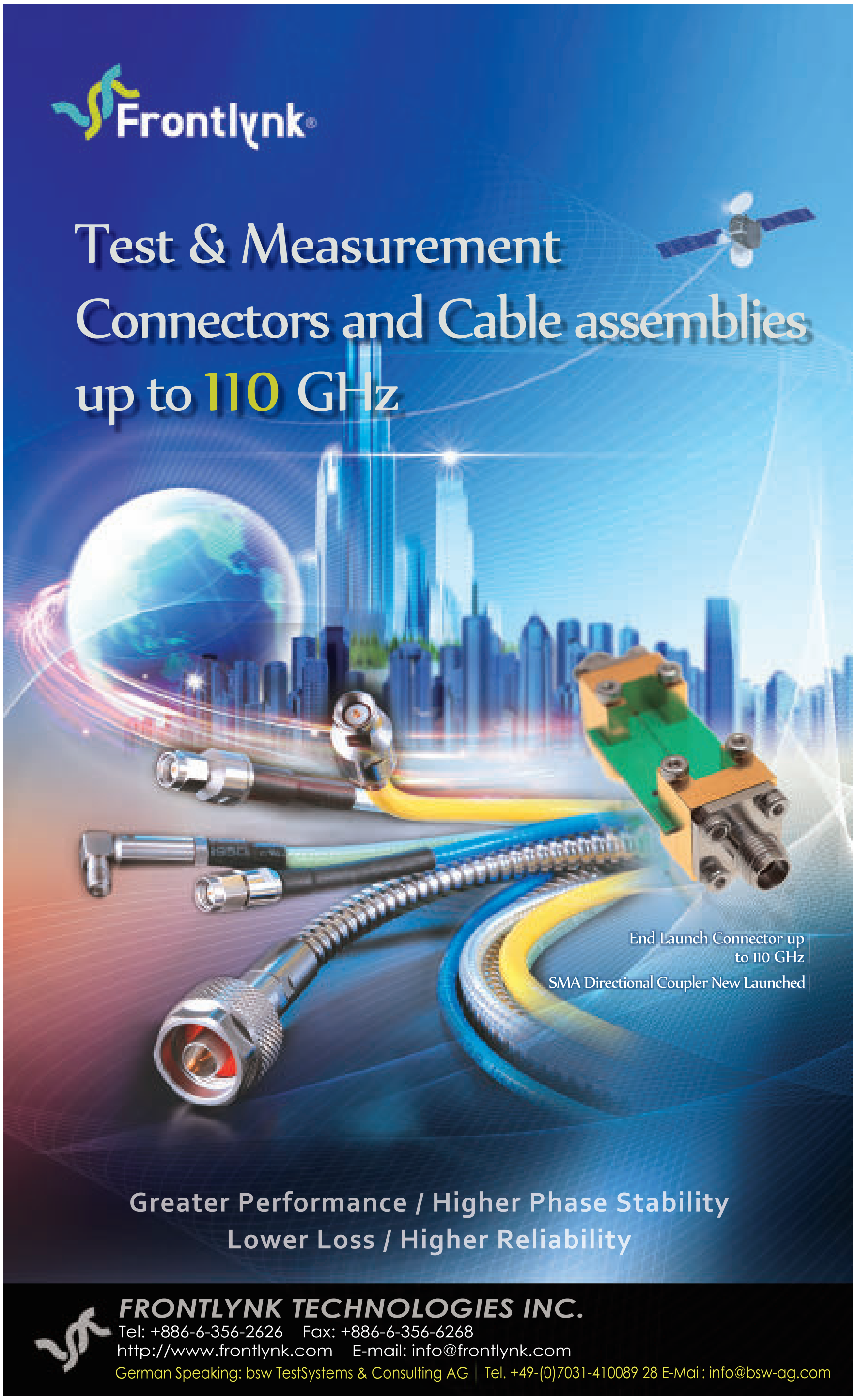
the concept of ‘material by design’ and the ability to control the RF macroscopic performance at the design stage with a multi-scale approach (from atomic/molecular to macroscopic behaviour) is becoming a new powerful tool in the hand of microwave engineers.

The RF and microwave sectors in Europe are steadily developing despite growing worldwide competition in the fields of mobile communication devices, manufacturing and R&D activities shifting to Asia.

Currently the European Union is preparing new frameworks through Horizon 2020 to strengthen the competitiveness of the micro-electronics and nano-electronics activities and preserve Europe’s strong position in these high-tech fields. In the Research and Innovation sector, it is evident that microwaves are pervasively entering into several work programmes. ICT is the most relevant together with security. Similarly, adequate investment in R&D is being undertaken by the European Defence Agency in the security sector where different kinds of microwave and terahertz sensors are being studied and developed.



...multi-disciplinary professional competence is becoming a ‘must’.

New trends in the education of microwave engineers are focusing on emerging technologies and innovative design techniques: multi-disciplinary professional competence is becoming a ‘must’. To maintain and grow microwave know-how, the professional status of engineers should be properly encouraged and recognized, for instance, by continuing certified education and by the institution of ‘chartered RF and microwave engineer’ status. Such professional acknowledgement should shape the education in the microwave domain, and enhance microwave engineers’ CVs. The spread of web technology enables and encourages distance education and collaborative projects among teachers and peers around the globe.

Europe is playing a significant role in the future development of RF and microwave technology. I am certain that EuMW and the EuMC conference in particular will provide new ideas and forge new paths in improving the quality of peoples’ lives around the globe.

ICs & Semiconductors

Sector overview by Franco Giannini, EuMIC 2014 Chair (In collaboration with Ernesto Limiti, Co-Chair, and Paolo Colantonio, TPC Chair)

This century semiconductor and integrated circuit technology, covering frequencies from microwaves to the submillimetre-wave region, have recorded major achievements, as will be demonstrated at the 9th European Microwave Integrated Circuits Conference (EuMIC).

One of the major challenges for RF integrated circuits is related to mobile communications, where industry faces an ever-increasing demand for higher data rates, more

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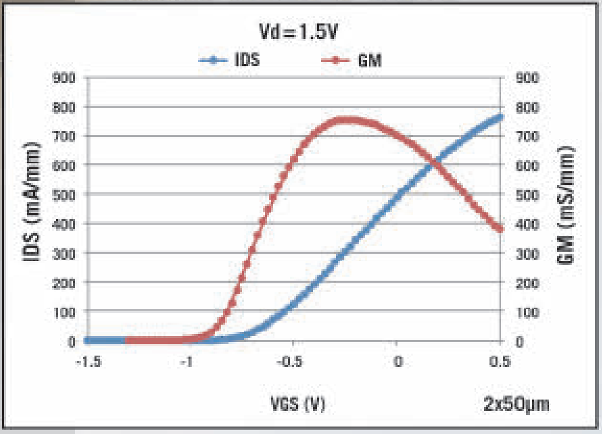

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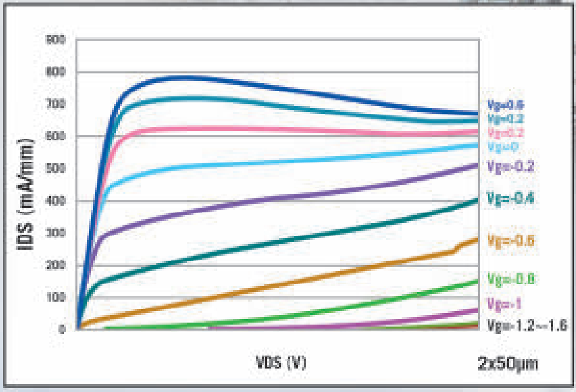
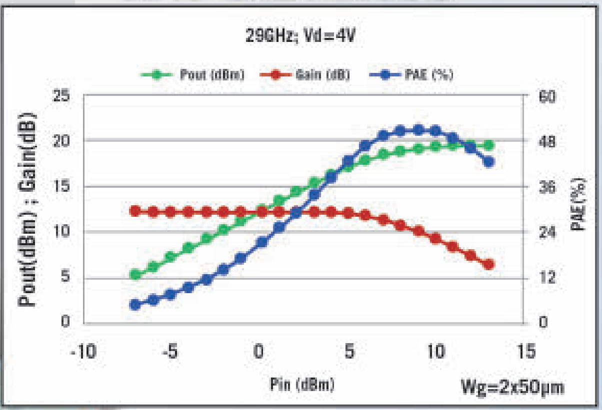
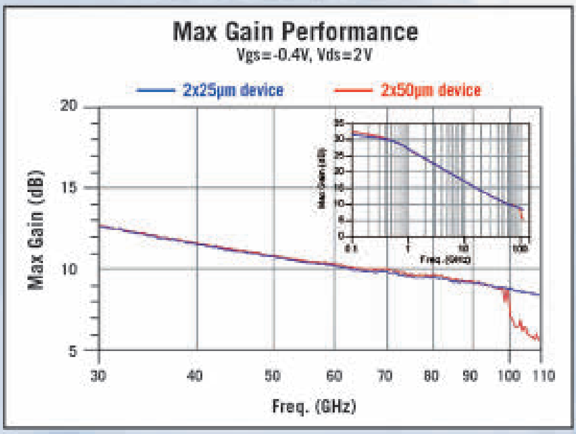


PP10 Load Pull Data



PP10 Max Gain



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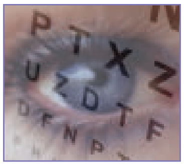
compact solutions and high performance front ends. Several contributors at EuMIC will demonstrate the remarkable progress in RF systems miniaturization and the reduction of total power consumption, both achieved through RF CMOS or similar technologies.

Regarding III-V semiconductor technology, the main trends demonstrated by the market to date indicate that GaAs will be the preferred semiconductor alloy for the majority of MMIC industrial users with a forecast of about 31 percent share by 2018. However, GaN technology is forecast to grow from its current 20 percent share up to 24 percent in 2018. Similarly, SiGe adoption continues, reaching an estimated 25 percent share in the same period.

Such microwave semiconductor technologies are playing a key role, not only in civil and defence systems, but also in the space environment for communications, remote sensing for Earth observation and radiometry. As an example, GaN HEMTs are becoming strategic, enabling components for both high performance and/or wideband Tx/Rx systems, as well as for very high power solid state transmitters. The impact of GaN technology is emphasized at system-level, enabling the reduction in size and cost, maximization of operational bandwidth and enhancement of detection.

After the completion of several significant research projects at the beginning of this century, these technologies are reaching maturity. EuMIC will offer a European perspective for the industrialization and exploitation of GaN and other technologies. A foundry panel session will divulge details of currently released and commercially available processes, together with those still in development and/or planned, with expected release dates and current status.

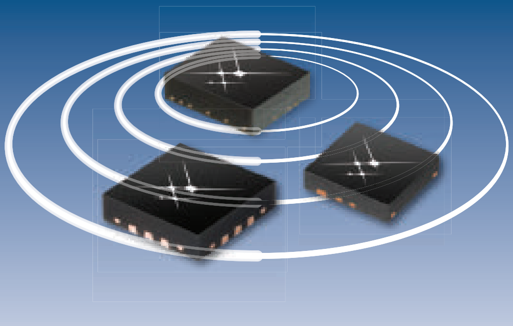
Radar



Sector overview by Enzo Dalle Mese, EuRAD 2014 Chair (In collaboration with Fabrizio Berizzi, TPC-Chair)

The radar sector is a growing research area for both industry and academia, mainly due to the huge expansion of civil applications, which is increasingly being demanded by the market. The 11th European Radar Conference assembles advanced high value scientific and technological contributions from industry and academia that demonstrates the technological growth in this sector. The main areas of radar development are: passive, imaging, antennas and miniaturization.

Passive radar uses the electromagnetic signals produced by illuminators of opportunity to enable radar functionality. The concept is not new, but the developments in digital hardware technologies and software capabilities have facilitated the practical realization of low cost operative systems. Currently, research is focused on the use of digital transmissions and satellite signals, which enable worldwide coverage. In addition, research is focused on the application of traditional radar concepts to passive radar, such as MIMO passive



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radar and imaging passive radar, as well as extending the platform to aerial and naval applications.

Imaging is becoming an essential feature of new radars and it is easy to predict that most future radar systems will have this option. The spatial resolution of this technique is improving, due to the increase of the long-term coherence of the transmitted waveform and the development of sophisticated super resolution techniques that make use of recent compressive sensing techniques. In addition, increasing the performance of the processing subsystems makes the real-time goal feasible. Imaging radars give a clear display of the target to the operator and improve the environmental situational awareness thanks to new graphical user interfaces. Finally, the high resolution of the target image addresses the automatic target recognition problem, resulting in dramatic improvement.

Imaging is becoming an essential feature of new radars…

Antennas are probably the most important radar subsystem. Future antennas will have reduced size; they will be active, with large bandwidth and often operate in an array configuration. Most are integrated in multifunction systems and are used both for radar and telecommunications. A good, high performance antenna is the primary subsystem that contributes to the overall performance of the radar.

In the near future one of the most important challenges will be to reduce size and weight, which is becoming a pre-requisite for many military and most civil applications, where low or very low power is essential, together with the need to minimise space and payload.

By taking advantage of the reduction of hardware (for example, software defined radar), allied to the progress in semiconductor power devices and integrated circuit development we could see radar on a chip become reality.

In summary, the radar sector is in a period of rapid and deep growth. It is not only benefiting itself from technological development but new radar innovations are often drivers for fuelling future technological progress.

CONCLUSION

As mentioned in the sector overviews, the European RF and microwave industry is healthy and playing its part in the evolution of technology and the implementation of innovation.

To enable such endeavours to come to fruition and benefit individual companies, partnerships, nations and Europe as a whole, it is imperative that Europe maintains a strong industrial base that can compete globally. Greater, uncomplicated business investments, a strong demand for European technological solutions and fewer obstacles to the commercial uptake of innovations are the keys to growth.

Horizon 2020 has been formulated to provide the mechanisms to make that possible. Now is the moment of truth when, over the coming years, we will discover if Horizon 2020 is truly visionary and can facilitate the transition necessary to take the EU industry forward and keep it competitive. ■


38GHz
60GHz
24GHz
79GHz

Envelope Tracking Comes of Age on Mobile Handsets

Kent Nickerson
BlackBerry (MIPI Alliance Member), Canada

The high value of scarce cellular radio spectrum and demand for ever higher data rates have spurred a great deal of innovation in optimizing mobile radio links, primarily by increasing signal bandwidth and modulation complexity. The consequences for RF transmitter power amplifiers (PA) are increased average output power and higher peak-to-average-power ratios (PAPR), which mean lower PA efficiency and disproportionately high power consumption. For mobile handsets, transmitter efficiency and battery life are not only reduced, but overheating becomes an issue as mobile PA footprints shrink and filter losses mount with new band interoperability and carrier aggregation requirements. Base station transmitters have long had the luxury of a stable antenna environment, complex support electronics, digital processing techniques and envelope tracking (ET).[1] ET has become viable for mobile devices and is now appearing in products. Given BlackBerry's years of internal and collaborative research in mobile radio, this article concentrates on ET for mobile LTE handsets. It also applies to any high PAPR transmitter used with WCDMA, HSPA, DTV and Wi-Fi.

Several means of increasing PA efficiency (ratio of RF power output divided by total supply power is used here) at less than maximum power have been employed in the mobile marketplace with varying degrees of success. Adaptive quiescent current bias has been widely used on PAs since the 1990s, while other PA designs simply bypassed the final stage for low power. A power-saving technique which has become especially popular in the past decade is "average power tracking" (APT). ***Figure 1*** shows the concept of APT, where the PA voltage supply, V_{PA}, is tailored on a frame-by-frame basis to the minimum required to accommodate modulation peaks for maintaining RF performance. This puts the PA slightly into compression to improve efficiency.

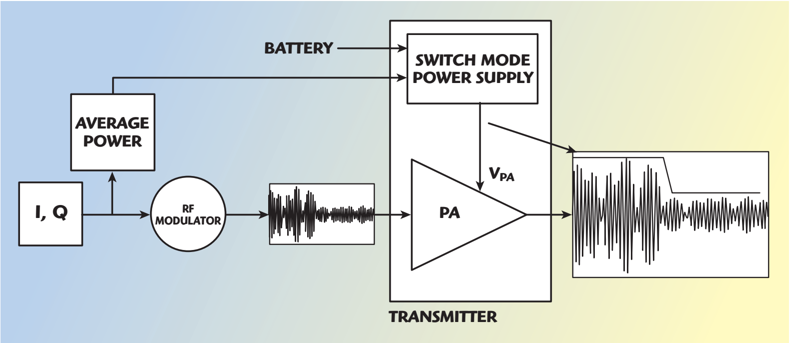

Fig. 1 Average power tracking (APT) transmitter.

Since the efficiency of concern to battery longevity is the product of the APT power supply and PA efficiencies, Figure 1 defines the "transmitter" to be optimized as the supply and PA together. Not only must the supply be efficient but V_{PA} must also have minimal noise so that it will not modulate the compressed PA and produce spurious RF products. Fortunately, the past decade has seen the nearly universal adoption of APT given recent improvements in the efficiency (nearly 95 percent), size and cost of low noise switched mode power supplies.

Handset transmitters most often operate at power levels significantly below maximum, and the above-mentioned schemes deliver value in reducing the amount of energy consumed at middle power levels. They do not, however, improve transmitter efficiency at high power which would reduce peak battery current and avoid overheating. Envelope tracking, in contrast, is most effective at high power and can also complement APT.

Figure 2 shows the concept of ET. Here, V_{PA} is generated by an ET power supply (ETPS) and applied to the PA's final stage at a level calculated from the instantaneous RF signal envelope, V_e. This operates the PA efficiently in controlled compression at all significant instantaneous powers. ET is not to be con-

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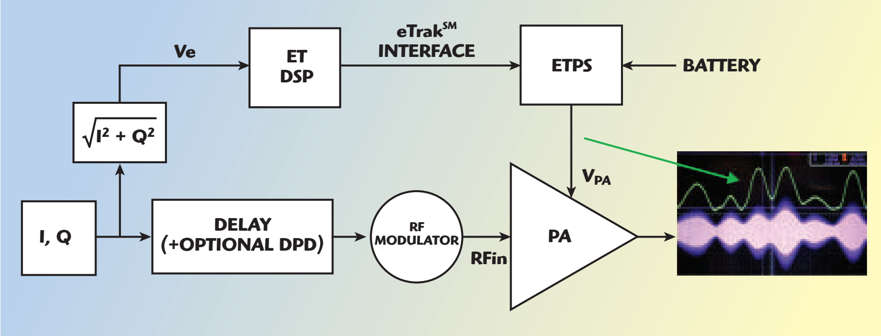

Fig. 2 Envelope tracking (ET) transmitter.

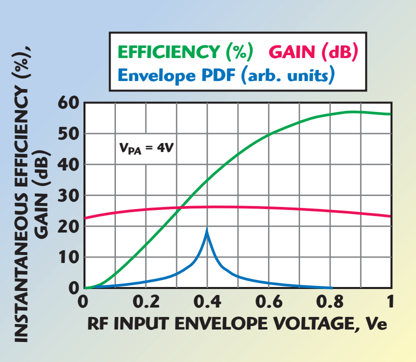

Fig. 3 Efficiency characteristics of a linear PA with constant supply voltage.

fused with Kahn's envelope elimination and restoration (EER) technique, since the PA RF input is fully modulated and V_{PA} does not have to track the envelope to very low values. The inset on the right of Figure 2 shows oscilloscope traces of the PA RF output and V_{PA} of an actual ET system.

EFFICIENCY OF APT OPERATION

Figure 3 shows the instantaneous efficiency (instantaneous RF output divided by instantaneous total DC input power) of a commercial two-stage InGaP PA module as a function of RF input envelope voltage. In this example, fixed supply voltages are applied to each stage, with a value of V_{PA}=4 V applied to the final stage. The envelope, V_e, as shown in Figure 2, is defined as the instantaneous RF input amplitude. If the RF input is generated by a modulator with quadrature components I and Q (the case in most mobile transceivers today), the envelope is proportional to the magnitude of the modulation:

$$V_e \propto \sqrt{I^2 + Q^2} \qquad (1)$$

As the PA is driven by higher input levels, efficiency improves as the final stage comes to fully utilize the supply voltage available to it. More drive puts the output into compression and output peaks are softly clipped, reducing gain and increasing distortion. In practice, a compromise is reached between efficiency and distortion (e.g., adjacent channel leakage ratio).

The lower trace of Figure 3 plots the probability density function (PDF) of the input RF envelope for an LTE QPSK modulated mobile uplink signal, which can have a PAPR up to 6 dB, so that envelope peaks are twice the average. It can be seen that the greater the signal PAPR, the lower the average signal level at the onset of significant distortion. For the LTE example shown, efficiencies of only about 35 percent are reached in APT mode with InGaP handset PAs. Factoring in a switching supply with 93 percent efficiency, APT transmitter efficiencies in the low 30 percent range can be achieved.

ET OPERATION

Figure 4 shows a family of efficiency curves for different fixed supply voltages from the same PA data used for Figure 3. The heavy black line connects points of maximum efficiency on the curves for each V_e. This defines a relationship called the ET look-up table (ET LUT) between V_e and the supply voltage, V_{PA}, which will maximize instantaneous efficiency at each point of the signal. The ET LUT, plotted below the efficiency curves of Figure 4, is applied by the ET DSP block in Figure 2. In practice, V_{PA} must maintain a minimum value for proper operation (0.6 V in this example) but there is little energy to save at very low values of V_e. The signal now spends most of the time at an efficiency approaching 50 percent, hence a significant increase in transmitter efficiency can be expected, assuming high ETPS efficiency.

A few practical considerations of ET can now be summarized:

- V_{PA} should be synchronized to the RF envelope by a small fraction of the symbol period, typically to 1 percent of the inverse signal bandwidth (e.g., one nanosecond for 50RB LTE signals) for mobile transmitters.
- The ETPS does not go all the way down to zero but has a defined minimum.
- V_{PA} is not necessarily a linearly scaled version of V_e, but in practice can be expected to be a monotonic function of it. This is a valuable consideration for the ETPS as this avoids cusping of V_{PA} at envelope minima and so minimizes its out-

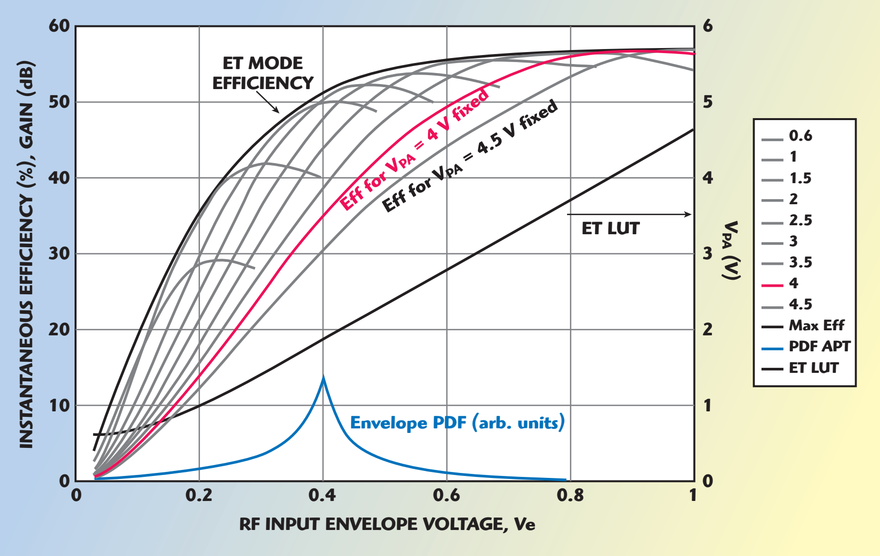

Fig. 4 Efficiency characteristics of a linear PA with envelope tracking.

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put bandwidth in operation.

- ET offers more potential improvement in efficiency as signal PAPR increases.

At first glance the concept of ET may appear technically daunting since the envelope tracking power supply (ETPS) of Figure 4 must be efficient, very fast, and yet produce very low output noise. Also, PA characteristics are complex enough without considering interactions with a dynamic power supply, so one might conclude that gross distortion would result. It will be shown, however, that ET can improve PA characteristics as well as save power.

Figure 5 displays characteristics of our mobile PA as contours of efficiencies and gain against V_{PA} and V_e. The ET LUT derived in Figure 4 which maximizes efficiency is readily traced on the contours of efficiency, as shown by the solid black line in (see ***Figure 5b***). Overlaying this maximum-efficiency ET LUT on contours of gain (see ***Figure 5a***), however, shows gain variation over the signal's excursion (shown in ***Figure 5c***), which is monotonic and no more than gain variation of APT with V_{PA} = 4 V.

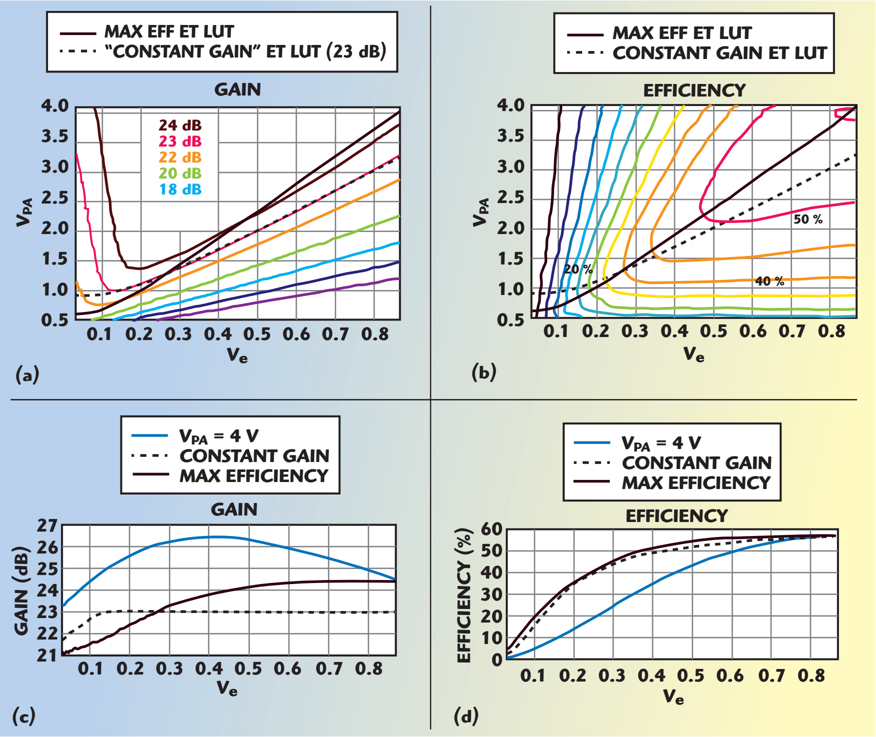
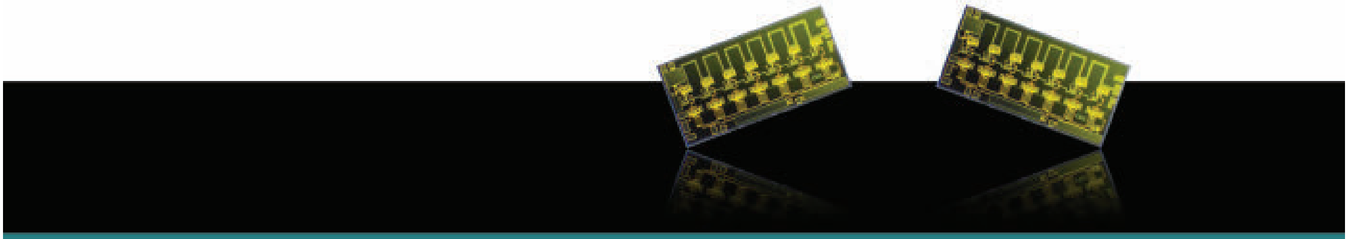
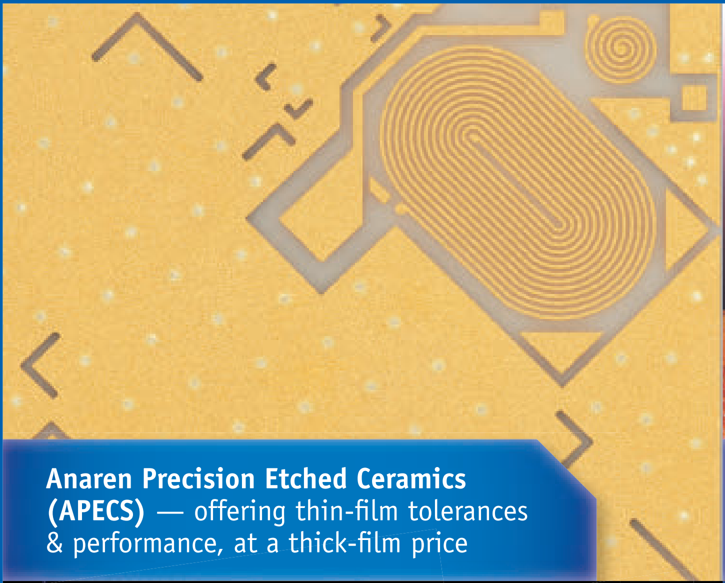


Fig. 5 Gain and efficiency characteristics of different ET LUTs.

Alternatively, consider the "constant gain" ET LUT shown by the broken black line in (see ***Figure 5b***), which follows a constant gain contour (23 dB in this case) except for low V_e, where it is kept at minimum V_{PA} for monotonicity. It offers flat gain at significant power and hence, high linearity, amounting to a form of amplitude predistortion. Remarkably, this ET LUT achieves nearly the same efficiency as the efficiency-optimized case, as shown in ***Figure 5d***. Since this does away with the need for input signal predistortion, at least for amplitude, the use of constant-gain ET LUTs is popular. Such linearization also allows the PA to be driven harder so that the envelope PDF peak can be increased to yield even higher efficiency. As a result, mobile PA module efficiencies approaching 60 percent have been achieved with InGaP PAs in ET operation.

The PA's phase response is also a source of distortion, but ET mode mobile PAs on the market have benign phase characteristics comparable to PAs optimized for APT operation. Phase-only predistortion with constant gain ET LUT is an option.





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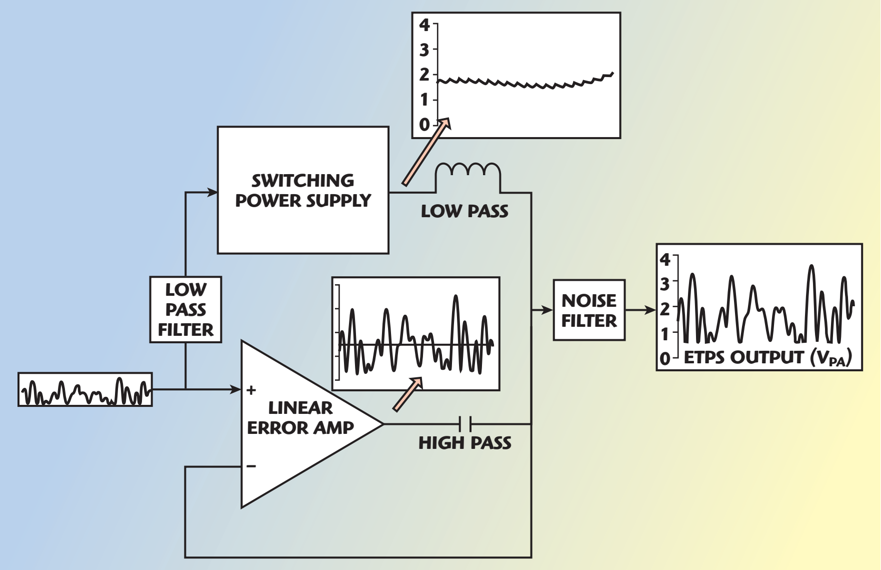
THE ET POWER SUPPLY (ETPS)

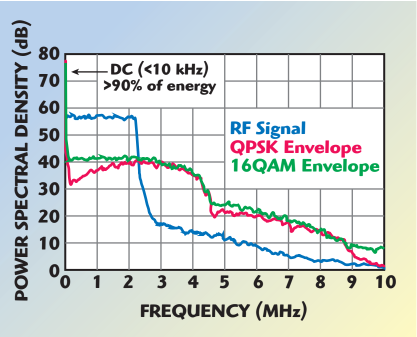
Higher PA efficiency will not translate to ET transmitter efficiency unless the ETPS is also efficient. High speed switching supplies are available which can effectively apply a mild form of ET for minimal extra cost, but these are not accurate or quiet enough for full tracking.

Figure 6 shows a simplified popular architecture which has been conceptually adopted with variants by many commercial ETPS manufacturers. It is essentially an APT supply coupled with a high speed, low noise linear error amplifier. On mobile handsets, changing from APT to ET operation results in small incremental size (less than 10 mm^2) and cost. In the implementation of Figure 6, the APT and error amplifier outputs are combined with a simple diplexing circuit which presents a low pass response to the APT output and a high pass path to the error amplifier.

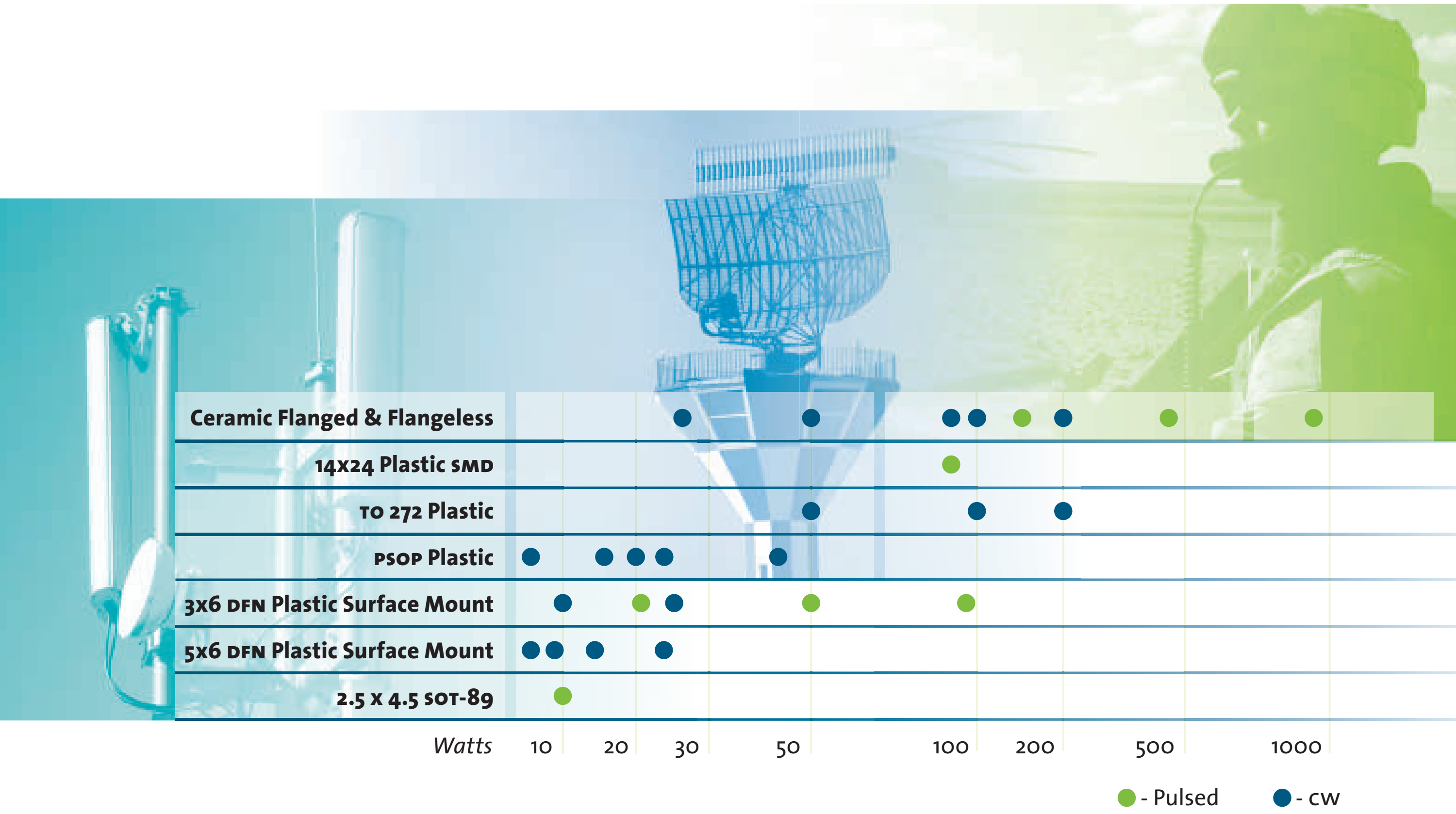


▲ *Fig. 6 ET power supply block diagram.*

While the error amplifier is quite inefficient, it does not have to supply much energy. ***Figure 7*** shows the power spectrum of an LTE 5 MHz uplink signal against the corresponding ETPS output (V_{PA}) power spectra for QPSK and 16QAM modulation. More than 90 percent of the energy is contained at frequencies below 10 kHz, which corresponds to shifts in power from frame-to-frame in LTE, and is well within the APT switching supply's capability. Only about 5 to 8 percent of the energy lies above 10 kHz for QPSK and 16 QAM modulations, respectively. At high power, commercial ETPS efficiencies of over 90 percent are common for WCDMA uplink signals, and 85 percent can be achieved even for 20 MHz LTE 16QAM. Higher bandwidths and efficiencies will soon emerge in the market. Regarding the ETPS frequency response for mobile LTE and WCDMA transmitters, industry experience and simulations[3] show that the ETPS output can be band limited to between 50 and 100 percent more than the nominal signal bandwidth while maintaining acceptably low levels of PA output distortion for mobile applications. Another special feature of the AC coupled design of Figure 6 is the ability of the ETPS output to momentarily exceed the battery voltage, which means that PA operation can be extended to higher



▲ *Fig. 7 Power spectra of LTE signals and envelopes.*



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voltages (with appropriate change of PA loading) even at end of battery life.

With ET efficiencies of over 50 percent and ETPS efficiencies of 90 percent, mobile ET transmitter efficiencies of 45 percent for LTE signals are being achieved at high power. Compared to a typical high power APT transmitter efficiency of 32 percent, ET promises less than 75 percent of the transmitter power consumption and less than 60 percent of the heat generation of APT mode at high power.

For less than maximum power, achievable ET efficiency and ETPS overhead power consumption erode ET's advantage. With mobile LTE transmitters, the ETPS linear amplifier is turned off and APT mode is resumed for medium output powers (typically 8 dB below maximum).

DESIGN OF ET POWER AMPLIFIERS

Power amplifiers designed for ET operation entail some minor modifications. Since the supply is modulated to frequencies somewhat higher than the signal bandwidth, bias bypass capacitors on modulated stages must be eliminated or minimized. A short supply trace from the ETPS to the PA in a handset can have an inductance of a few nH, so an accurate supply drive to 30 MHz for a 20 MHz LTE signal sets an upper limit of about one nF total shunt capacitance for all PAs driven. A hazard of minimizing local PA bypass capacitance is RF parametric stability, especially at low frequencies, but major mobile PA manufacturers are now producing suitable devices.

Since the PA may be loaded for higher voltage operation, transistor breakdown voltage should be increased. Higher voltage and compressed operation also reduce power gain, so gain may have to be increased a few dB to achieve required output power with existing transceiver RF output power capability. This makes attention to stability even more critical.

PA gain should not be too sensitive to V_{PA}. This allows a healthy excursion of V_{PA} with minimal gain variation so that ET mode efficiency can be maximized. Excessive gain expansion against input power should also be avoided. The RF phase response along the expected ET supply response should also be minimized and monotonic if possible.

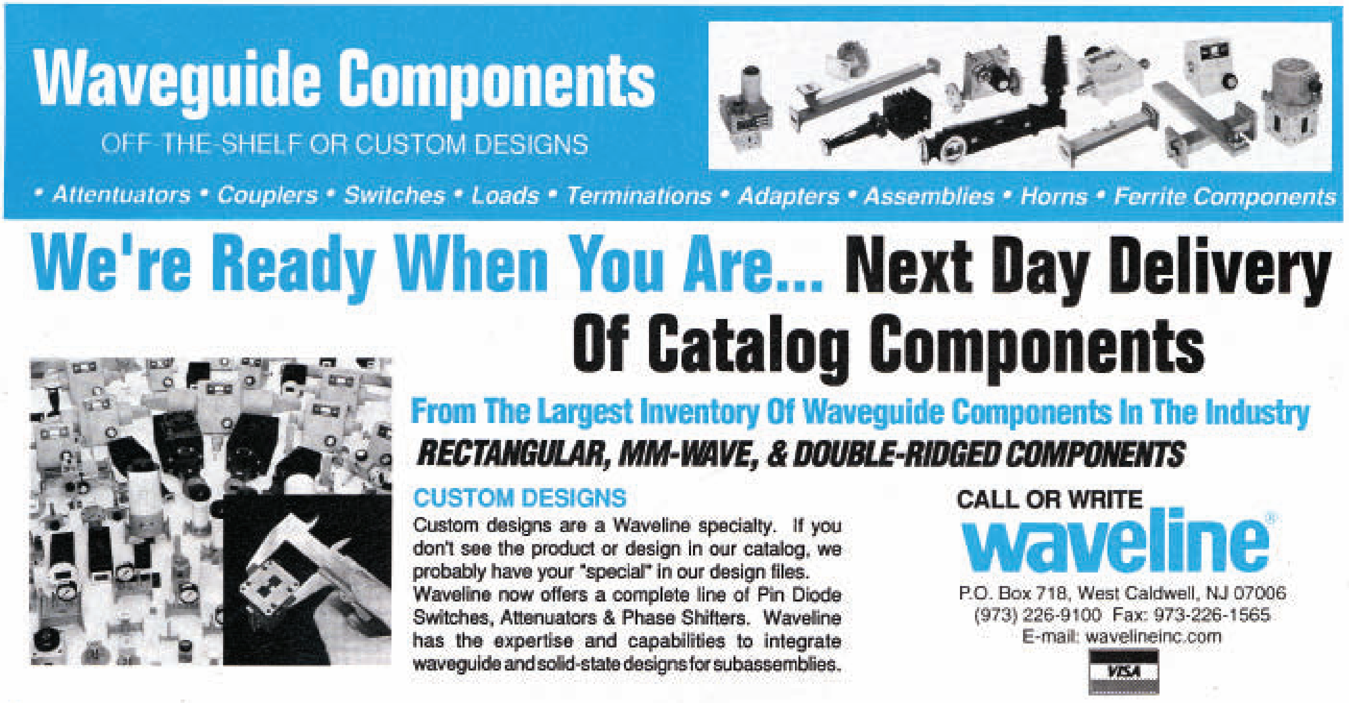
Cautious application of ET will see V_{PA} applied only to the final stage of the PA, with previous stages operated from fixed voltages, since modulating multiple stages simultaneously makes ensuring stability and well behaved dynamic characteristics even more difficult. Nevertheless, handset PAs with ET applied to two stages simultaneously have emerged in the market as PA manufacturers gain design experience, allowing somewhat higher transmitter efficiency.

CHALLENGES

An ET system introduces some new but tractable design challenges:

Noise Conversion: Since PA gain is a function of supply voltage, supply (V_{PA}) noise can modulate the RF output and manifest as spurious RF noise outside of the desired signal. Such noise conversion is quite large with ET PAs as they operate in efficient compression over most of the envelope. In frequency duplexed systems like WCDMA and LTE-FDD, this can become a critical problem if supply noise at frequencies close to the duplex spacing converts into the receive band as interference. With ET, unlike APT, the supply contains spectral energy exceeding the RF signal bandwidth, which can come close to the duplex frequency of some bands (e.g. Bands 2 or 17), making adequate voltage supply filtering critical. While this has proven to be a significant problem in handset ET transmitters, it is successfully mitigated with painstaking attention to ETPS design, filtering, and component layout.

Load Impedance Changes: PA gain is also a strong function of its load impedance. Changing impedance at the PA final transistor necessitates changing the scale of both the RF input drive and V_{PA}, and by different factors, to maintain optimum ET performance. Even apart from large mobile antenna impedance shifts, the PA faces duplex filters which have significant impedance variation over frequency and temperature. This can make for tedious characterization and calibration. This

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problem is common to APT transmitters, however, and ET transmitters appear to suffer no more - if not less - distortion over uncompensated mismatch than APT.[2] Active antenna tuning is also starting to appear as a handset feature, along with antenna line impedance estimation, to stabilize antenna impedance and compensate its effects.

Memory Effects: PA characteristics are typically modeled quasi-statically for ET operation, so that the output is an instantaneous function of V_{PA} and RF input power. As the speed of modulation increases, intrinsic PA memory effects such as junction charge storage and bias network response can become significant. The ETPS can suffer slew rate limitations and rising V_{PA} supply line impedance. Resultant distortions can become apparent in mobile handsets for RF modulation bandwidths of 20 MHz. Higher bandwidth applications in the future will require careful attention to memory effects.

Filter Group Delay: In addition to significant impedance changes in the pass band, high order duplex filters on the transmitter output (and in some cases, input) are characterized by large and variable group delays which can approach a symbol period across the RF signal bandwidth. While OFDM signals used for LTE and Wi-Fi are resistant to this, the signal envelopes are not. An investigation by the author suggests that output duplexers can add doubly delayed and distorted reflections from the duplexer's antenna side to combine with and distort the envelope at the PA output, causing suboptimal tracking. This constitutes a sort of memory effect, and this can be minimized by good PA transmission line matching.

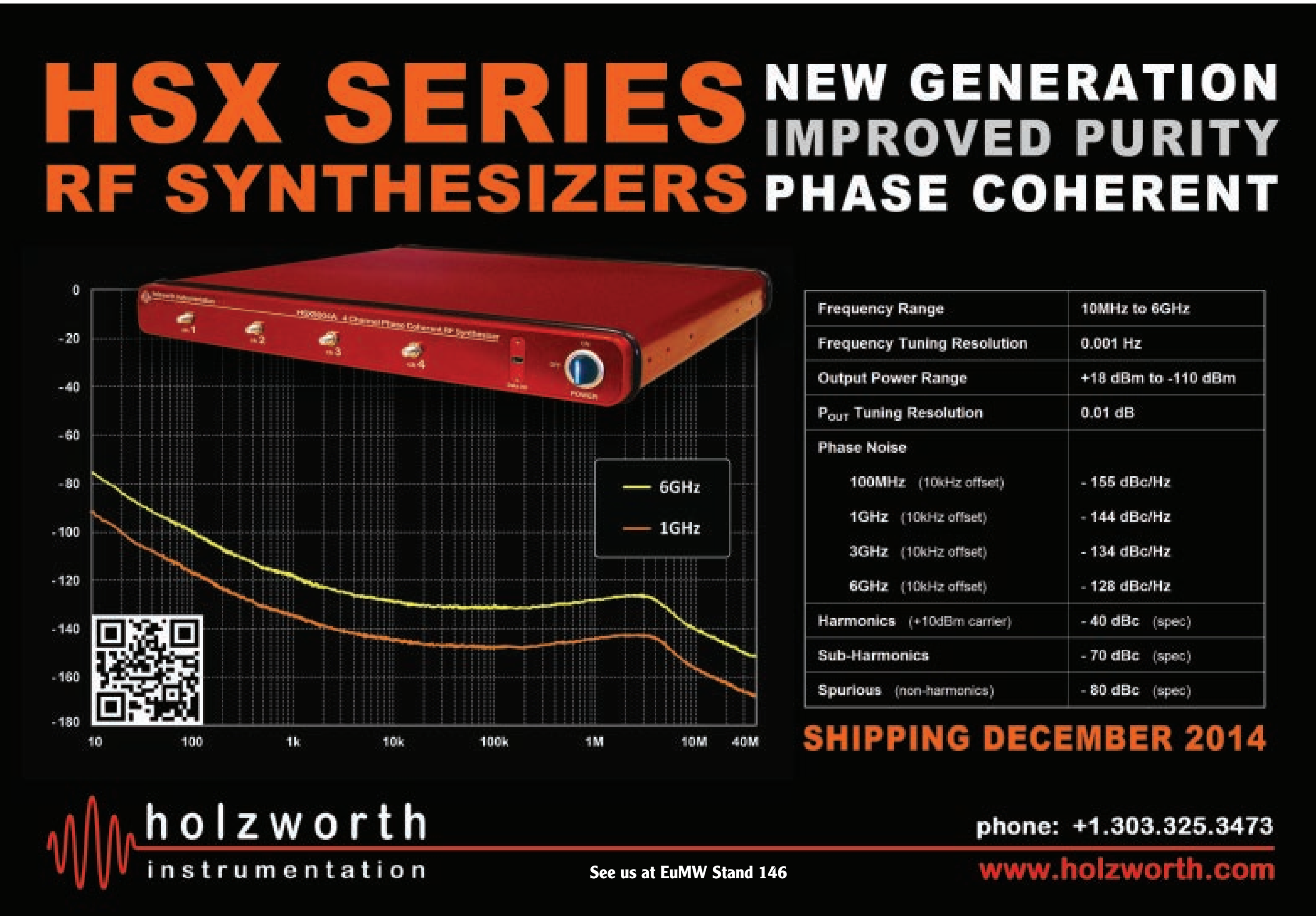
THE ROLE OF MIPI®

The ETPS must supply the PA with high fidelity, accurate timing and low noise, so its control is as critical. This begs design guidelines and specification of the interface between the ETPS and the controlling transceiver or processor. In the middle of 2011, manufacturers of RF transceivers, modem processors and OEMs chartered the Analog Control Interface Working Group (ACI WG) within the MIPI Alliance to develop control interface specifications which impact analog chip-to-chip connections. Within that WG, an envelope tracking sub-group was formed to specifically address the interface between the transmitter and envelope tracking power supply. They defined a differential analog voltage ETPS control interface dubbed "eTrak^{SM}", which is shown in Figure 2. The first version of the specification was released in October 2013.[4] Further versions are being drafted.

The eTrak specification prescribes control signal amplitude, accuracy, frequency response, drive capability and spectral noise limits. The ACI WG has also developed an extensive application note[3] which discusses many design challenge topics researched by group members, as well as technical recommendations, such as slew rate and ETPS common mode rejection. A suite of bench verification tests[5] is currently being drafted.

ET IN THE FUTURE

While signal bandwidths of up to 20 MHz are presently targeted for mobile products with ET, higher sig-



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nal bandwidths and PAPR demanded by LTE-Advanced carrier aggregation (PAPR of 9 dB or more) and 802.11 will require better error amplifier high frequency performance. PA memory effects will have to be reduced and unless band allocations and duplex spacings are increased, dispersive effects of filter components will become more severe. Higher integration of ET components will be necessary to minimize PA supply line issues. Efforts are underway to integrate ETPS with CMOS PAs for better ET supply coupling and integration with front end components, as well as compensation of historically lower CMOS high frequency efficiency and linearity. Antenna tuning solutions, such as that offered by BlackBerry's Paratek™ technology, are emerging to mitigate mobile antenna load variance and duplexer dispersion.

CONCLUSION

Evolving mobile RF transmitters are trending to higher power operation with higher PAPR signals which demand higher transmitter linearity. This compromises transmitter efficiency and creates significant heat dissipation problems in mobile handsets. ET can increase efficiency, dramatically reduce PA heat dissipation, and improve signal quality at high power, making it an excellent complement to existing transmitter power saving techniques. MIPI's ACI WG has provided specifications, design guidelines and a test suite to facilitate implementation. Components supporting ET are available from several manufacturers and are now mature and economic enough to start appearing on advanced mobile handsets. ■

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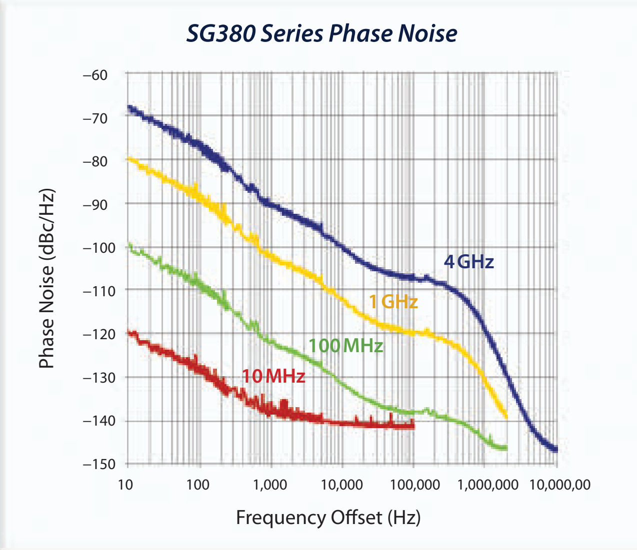
Kent Nickerson *received his Bachelor's degree in Physics from University of Waterloo in 1981. His master's degree in electrical engineering from McMaster University (1986) included research and construction of an experimental radar system. He has designed and built photonic systems for control of phased array radar and electro-optic sampling of MMICs, and is a member of the Optical Society of America. As principal scientist of RF Research at BlackBerry, he develops advanced mobile handset transmitters. Nickerson is also a member of MIPI Alliance (MIPI), a global organization that develops interface specifications for mobile and mobile-influenced industries.*



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−80
−90
−100
−110
−120
−130
−140
−150
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100
1,000
10,000
100,000
1,000,000
10,000,00
Frequency Offset (Hz)
4 GHz
1 GHz
100 MHz
10 MHz

Maximizing RF Spectrum Utilization with Simultaneous Transmit and Receive

Charles H. Cox III and Edward I. Ackerman
Photonic Systems Inc., Billerica, Mass.

An RF front end device called the Transmit Isolating Receiver (TIRx) takes the place of both a circulator and low noise amplifier in a conventional RF front end, enabling full-duplex wireless communication by transmitting and receiving simultaneously on the same frequency through a single antenna. The TIRx RF front end enables single channel full duplex communications by providing a high degree of T/R isolation, exceeding 40 dB over four decades of bandwidth. When combined with appropriate digital interference cancellation, systems delivered with the TIRx RF front end have achieved >80 dB of T/R isolation over multiple frequency bands even when connected to an antenna with poor return loss.

Wireless services are expanding exponentially with more and more users demanding ever-wider bandwidth. At the same time, the RF spectrum supporting these services is constrained by market forces and government regulations. Acquisition of additional spectrum involves huge capital expenditures for its purchase, infrastructure installation and support.

Within current spectrum allocations, the frequency channels for various services are either separated to avoid interference or are further subdivided into separate uplink and downlink sub-channels. This results in an inefficient utilization of RF spectrum that could be alleviated with simultaneous transmit and receive (STAR) on the same frequency channel, also known as full-duplex operation. Potentially, such full-duplex operation could more than double the capacity of current wireless systems. It could also help solve important problems with current networked systems that affect the Quality of Experience (QoE) and provide future opportunities for new enhanced services.

The key challenge to implementing STAR is protecting the receiver from the high powered transmit signal to a sufficient degree; the figure of merit that quantifies the degree of protection is known as transmit-to-receive (T/R) isolation. The T/R isolation required is dictated largely by the transmit power and the receiver noise level, and varies from a minimum of about 40 dB to well over 100 dB for various applications. For example, as noted by Choi et al.,[1] IEEE 802.15.4 personal area networks (e.g., ZigBee) use 0 dBm transmit power and the noise floor in the receiver is around -100 dBm. Thus, as much as 100 dB of T/R isolation within the de-

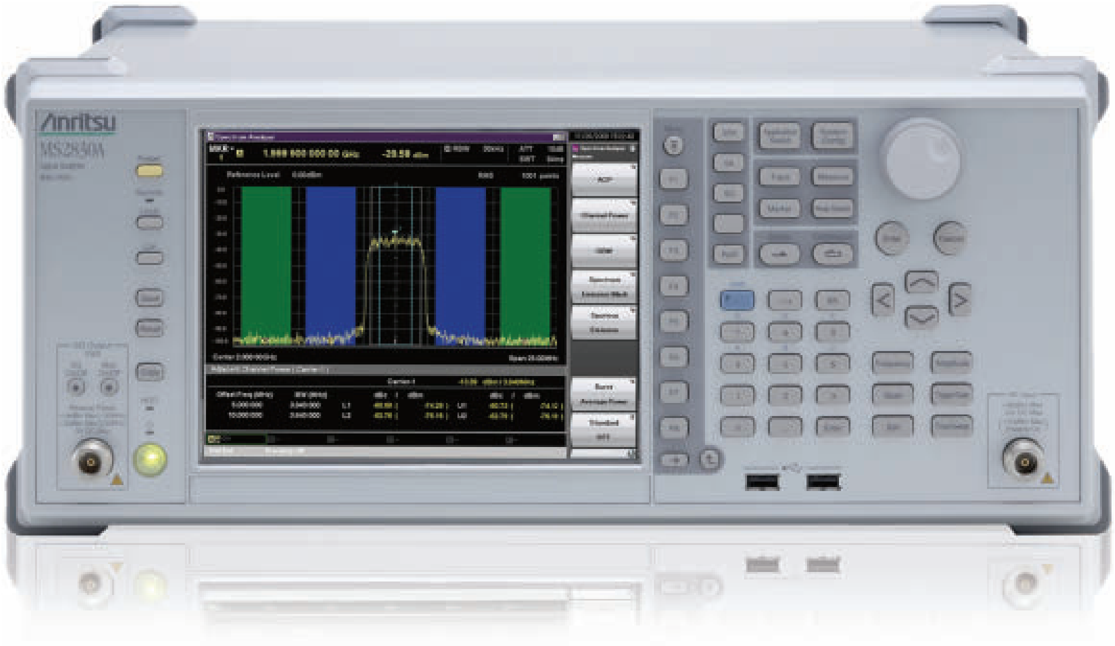
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TABLE I

DESIGN GOALS FOR SIMULTANEOUS TRANSMIT AND RECEIVE PHYSICAL LAYER

Parameter	Value	Rationale
Transceiver Architecture	Transmit and receive through same wideband antenna	A single antenna solution minimizes system size, weight and cost. Also compatible with MIMO and small array based systems.
Bandwidth of Operation	100 MHz to 6 GHz	Covers the majority of defense communication systems, cellular networks and wireless LANs including Wi-Fi bands
Isolation	40 to 100+ dB	Supports MAC for multiple network topologies
Transmit Power Handling	Up to 20 W	Desired for higher powered site locations

vice is required in such networks to avoid self-interference.

Since many of today's wireless devices have multiple antennas to support multiple input, multiple output (MIMO) processing, one possible way to achieve isolation is to use separate antennas for transmit and receive. Within small devices such as tablets and phones, only a few centimeters of separation is possible, making it difficult to achieve the significant T/R isolation required. Also, for many applications, it is desirable to use the same antenna for both transmit and receive to maximize system flexibility and performance and minimize cost.

If the same antenna carries both transmit and receive signals on the same frequency channel, the conventional approach is to use an RF circulator instead of a frequency diplexer to separate them. Unfortunately, conventional RF circulators based on the use of ferroelectric elements can achieve only about 20 dB of isolation over an octave bandwidth. Much deeper isolation nulls are available, but these cover only a narrow bandwidth. Active electronic circulators have been developed, but their isolation versus bandwidth performance is about the same, and they cannot withstand high transmit signal powers.

Photonic Systems Inc. (PSI) has been investigating this full-duplexing problem for both defense and commercial wireless applications in order to develop a physical layer (PHY) solution applicable to a wide range of wireless networks and devices, as shown in ***Table 1***. A major goal of this development is a transceiver architecture that is broadband without requiring separate transmit and receive antennas. This would exploit all the benefits of MIMO systems and provide the most degrees of freedom for the receiver's digital signal processing, thus maximizing spectrum utilization and network performance. Achieving broad bandwidth depends upon the availability of a wideband antenna, but this architecture could also be used with, or retrofitted into, installations with narrowband antennas.

A high degree of isolation – at least 40 dB to satisfy initial needs, but ideally 80 dB or more – is desired to support a broad range of media access control (MAC) topologies. A goal of up to 2 W transmit power works with many types of cellular and Wi-Fi installations. An additional goal not stated in Table 1 is to provide a solution whose cost is consistent with existing economic models for wireless services.

DESIGN CONCEPT

Most RF circulators work by summing and differencing the RF phase of two waves travelling in opposite directions around the circumference of a ferrite disc. The isolation is achieved by the constructive interference between the two waves at one port of the device and destructive interference at the other port. This approach is inherently narrowband, resulting in bandwidths appreciably less than an octave, although some broader-band circulators have been developed by sacrificing isolation.

In contrast to ferrite-based RF circulators, the approach described here leverages photonics to extend both bandwidth and isolation simultaneously, as illustrated in ***Figure 1***. One might think of this as a photonic circulator, but in addition to achieving the functionality of an RF circulator, it also provides receive signal gain with a low noise figure like an RF low noise amplifier (LNA). It is, therefore, more appropriately called a transmit-isolating receiver RF front end, or TIRx.[2]

Figure 1a illustrates the operational principle. To achieve broad-bandwidth isolation, a balanced drive optical Mach-Zehnder modulator is used.[3] In a balanced drive modulator, applying the same signal to both electrodes results in the same optical phase modulation being applied to each arm. When the two arms recombine (as shown in blue), the result is – at least ideally – no intensity modulation of the optical carrier. To implement a TIRx, the transmit signal is applied to both of the TIRx drive ports, resulting in no modulation of the CW laser light. Thus, as desired, the transmit signal travels along the modulator electrodes directly to the antenna but is not conveyed to the TIRx receive output port. The receive signal from the antenna, however, is applied to only one of the modulator's electrodes, resulting in efficient unbalanced modulation of the optical carrier. The resulting optical modulation is detected at the receive port of the TIRx.

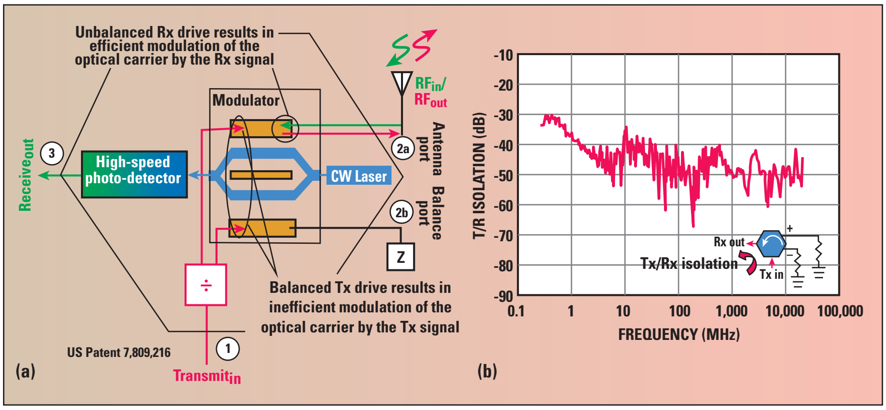
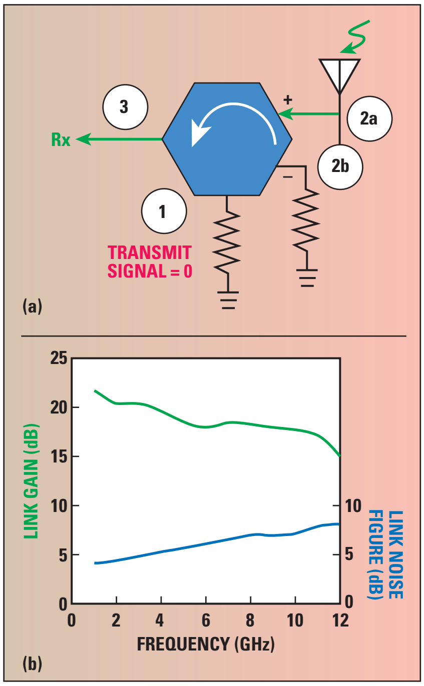


Fig. 1 *TIRx theory of operation (a), and measured T/R isolation (b).*



▲ *Fig. 2 TIRx connection for receive functions (a); measured gain and noise figure (b).*

Since balanced drive operation extends "from DC to daylight," this is – in principle – a mechanism for achieving high isolation over an extremely broad bandwidth. ***Figure 1b*** is a plot of the measured T/R isolation versus frequency for a TIRx showing >40 dB of isolation over four decades of bandwidth with a 50 ohm load in place of the antenna.

As shown in ***Figure 2a***, the TIRx has only RF input and output ports, but inside it contains a complete RF photonic link. The photonic components include a CW laser, an optical modulator and a photodetector. While previous photonic links had high noise figures (typically >20 dB) and high insertion loss, photonic links with low noise figures and positive link gain have been recently demonstrated (see ***Figure 2b***).[4] This illustrates the second function of a TIRx: its receive path has RF power gain and a low noise figure (like an electronic LNA). In the wireless service bands between 700 MHz and 6 GHz, the measured data in Figure 2b show the noise figure varying from 4 to 6 dB and the gain from 17 to 21 dB. These are useful values for most wireless network applications.

Since the transmit signal passes through the device, it is important to quantify its power handling capability. The current carrying capability of the electrodes of the optical modulator limits the power handling of the device. Present optical modulators have been shown to withstand 20 W (43 dBm) of transmit power through typical TIRx devices.

Compared to ferrite-based RF circulators, the TIRx has much higher T/R isolation over much greater bandwidth; however, when either device is terminated in 50 ohms, partial reflection of the transmit signal by an actual (not perfectly 50 ohm) antenna at the bi-directional port back into the receiver path will degrade the isolation across a broad bandwidth. It is theoretically possible to counteract this effect by improving the impedance match to the antenna, but it is physically unrealizable to achieve the required combination of bandwidth and antenna return loss improvement required to meet the STAR requirements in Table 1 because such a combination of bandwidth and impedance match exceeds the Bode-Fano limit.[5]

The TIRx has a different way of addressing this issue via the fourth port as shown in Figures 1a and 2a. The approach is to connect a variable impedance to this port that replicates the antenna impedance versus frequency. Unlike impedance-matching that attempts to transform one impedance to another, and is bandwidth-limited per Bode-Fano, there is no limit to the degree that one impedance can replicate another. This "Antenna Balance" port balances out the impedance variation of the antenna. With reference to Figure 1a, at any frequency where the impedance presented at the two bidirectional ports are equal, the transmit signal at Port 1 is routed to the antenna connected to Port 2, and the signal received by the antenna is routed to Port 3. But Port 3 is substantially isolated from Port 1 because even the portion of the transmit signal that is reflected by the antenna back into Port 2a is exactly balanced by the portion of the transmit signal reflected back into the "balance" Port 2b by the impedance that is connected to the fourth port. Therefore, the front end will have excellent T/R isolation. This is one important feature of the TIRx that distinguishes it from conventional ferrite circulators.

By itself, the analog cancellation capability of the TIRx is not enough to achieve the isolation goals in Table 1

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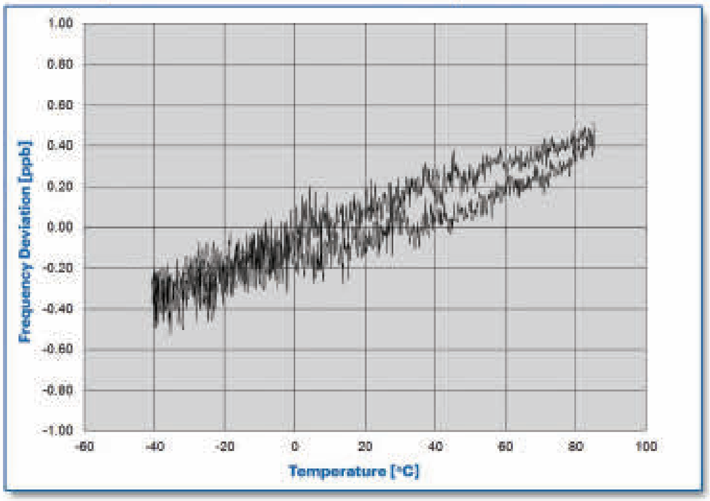

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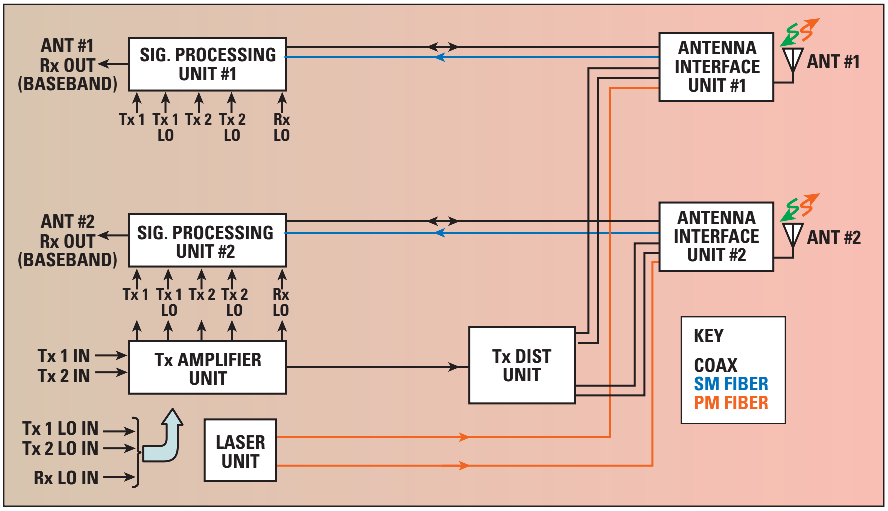
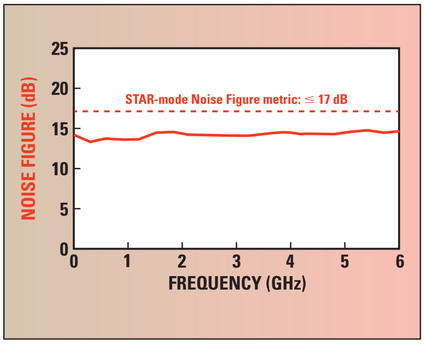


▲ *Fig. 3 Block diagram of the proof-of-concept, full duplex, demonstration system.*



▲ *Fig. 4 Plot of demonstration system STAR-mode noise figure versus frequency.*

mainly due to limitations of the optical modulator and differences between the antenna impedances and the balance. If, however, the analog front end suppresses the transmit signal in the receive channel to a degree that will sufficiently ensure linearity in that signal path, digital signal cancellation can further improve the T/R isolation. In digital cancellation, an estimate of the interfering signal is subtracted from the received signal in the digital domain. Since the transceiver "knows" the signal it is transmitting, a good (but not a perfect) estimate of the interference is available.

PROOF OF CONCEPT DEMONSTRATION

Figure 3 shows a block diagram of a two-channel proof-of-concept demonstration system requiring 40 dB of T/R isolation in a 1 MHz to 6 GHz bandwidth. The system consists of a pair of customer-supplied broadband antennas, two TIRx front ends and a pair of signal processing boards. The CW laser for the optical modulator is located remotely from the antenna via about 150 feet of polarization-maintaining (PM) fiber. Similarly, the signal received by each antenna is carried to the signal processing boards over a single-mode fiber. Two copies of the transmit signal, necessary for STAR operation of the TIRx, are supplied to each antenna interface unit over coaxial cable.

The system is assessed for a large number of performance parameters, a few of which are discussed. One of the important STAR parameters is receive noise figure versus frequency, a plot of which is shown in ***Figure 4***. The broad bandwidth capability of photonics is evident in this plot, which shows a relatively constant noise figure less than 15 dB over the entire frequency range of 1 MHz to 6 GHz. It is important to note that in STAR-mode there is no electronic LNA; the TIRx is connected directly to the antenna element. The noise figure, however, is higher than might be desired for demanding applications. As shown in Figure 2b, lower noise figures have been demonstrated using more sensitive modulators.

Another important receive parameter is the spurious-free dynamic range (SFDR). In STAR operation, there is a potential for intermodulation products to be generated between transmit and receive signals in addition to intermodulation products generated between two receive signals. For the demonstrated system, the receive-channel SFDR in the absence of a transmit signal is 113 dB·Hz[2,3]. The SFDR limited by mixing with the strong (2 W) transmit signal is ≥42

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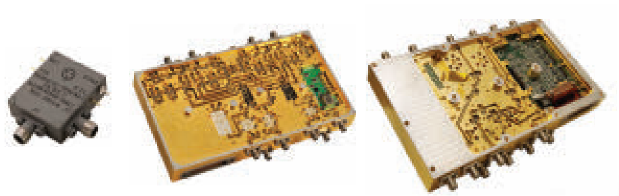

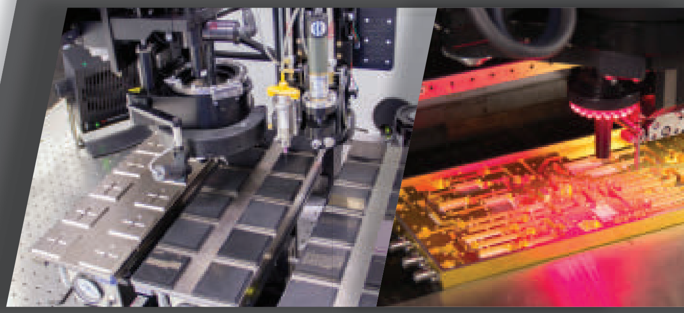

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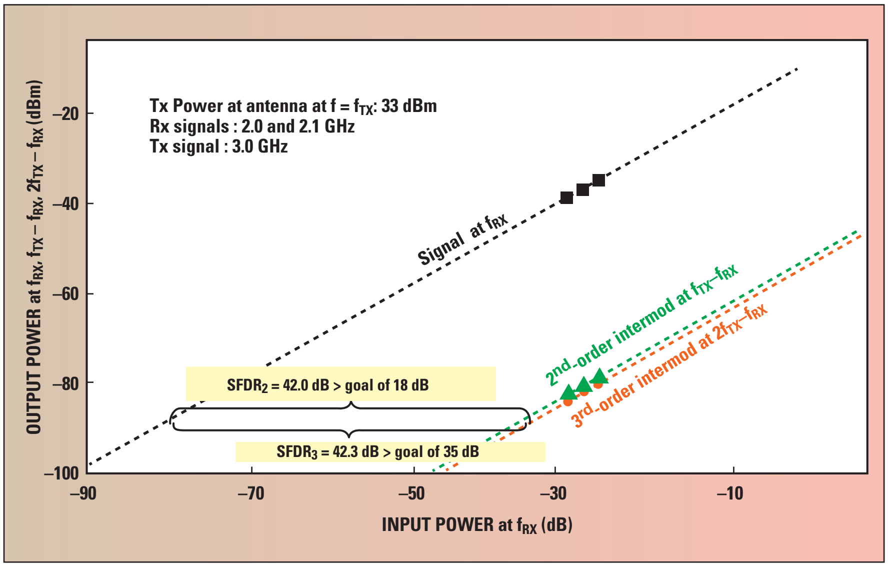
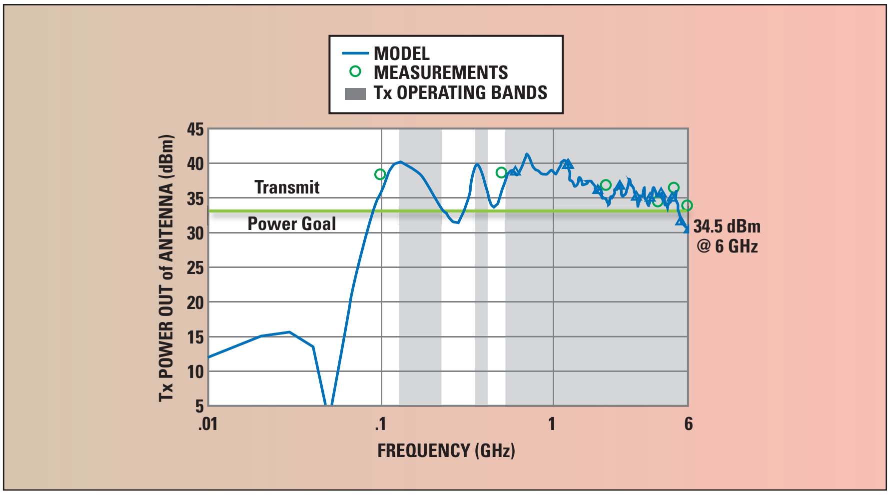


▲ *Fig. 5 Plot of 2nd and 3rd order SFDR versus receive power for a transmit power of 2 W.*



▲ *Fig. 6 Plot of transmit power from the antenna versus frequency.*

dB, as shown in ***Figure 5***.

One aspect of Tx-Rx intermodulation is that both have a slope of 1, unlike Rx-Rx intermodulation with slopes of 2 and 3, respectively. To understand the basis for this difference, consider the following: in the case of receive-receive SFDR, the strongest second-order intermodulation products are f_{RX1}-f_{RX2}, f_{RX2}-f_{RX1}, and $f_{RX1}+f_{RX2}$, and the strongest third-order intermodulation products are 2 f_{RX1}-f_{RX2} and 2 f_{RX2}-f_{RX1}. In the case of transmit-receive SFDR the strongest second- and third-order intermodulation products are, respectively, $f_{TX1or2} \pm f_{RX1or2}$ and 2 f_{TX1or2}-f_{RX1or2}. One can see that the receive frequencies appear twice or thrice in each of the intermodulation products that determine, respectively, the second- and third-order receive-receive SFDR, whereas they appear only once in each of the intermodulation products that determine transmit-receive SFDR. Therefore, in a plot of transmit-receive SFDR, the second- and third-order intermodulation distortion products both have a slope of 1 (see Figure 5).

In the STAR transmit path, an important parameter is the transmit power because the RF transmit signal passes through the TIRx along the modulator's electrodes. For the demonstration system, the application goal is 2 W of power transmitted from the antenna at any frequency where the antenna return loss is less than 7 dB. Applying this constraint results in the bands shown in ***Figure 6***, a plot of transmit power from the antenna versus frequency. It is interesting to note that achieving transmitted power

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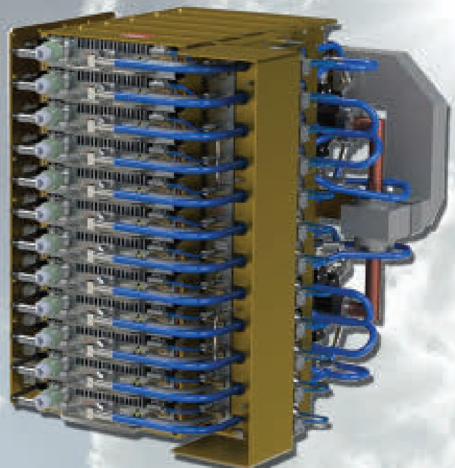


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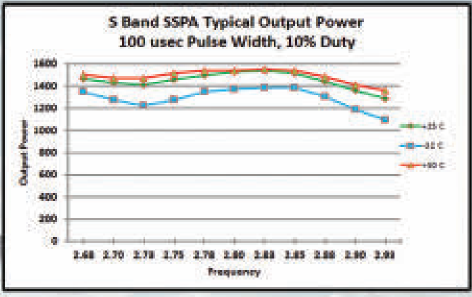
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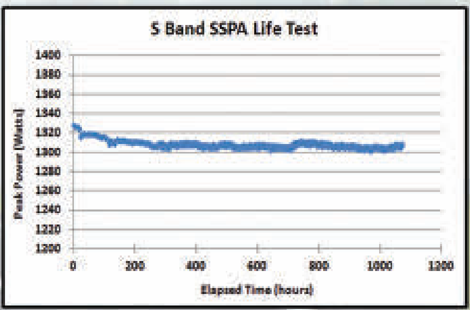
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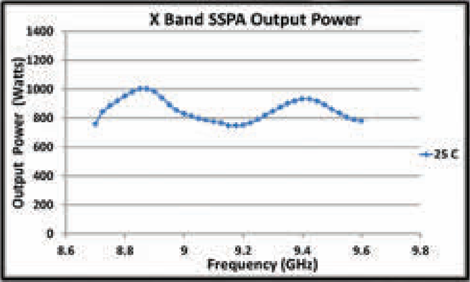
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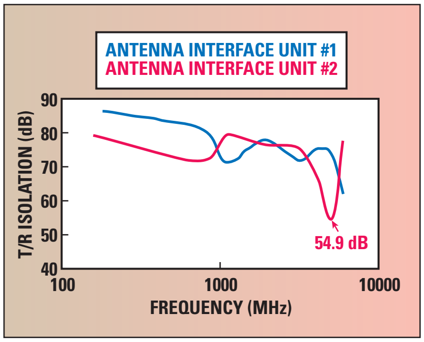
of 2 W from an antenna with a return loss of 7 dB corresponds to 0.5 W of transmit power reflected back into the receive path. Modeled and measured results show ≥ 34.5 dBm out of the antenna from 500 MHz to 6 GHz, exceeding the goal.

The key STAR parameter is T/R isolation. As noted earlier, the system shown in Figure 3 employs a two-step approach to achieve high isolation over a wide bandwidth when transmitting and receiving simultaneously via a single antenna. The first step takes advantage of high TIRx isolation. This reduces the linearity requirement on the subsequent components in the receive path by suppressing the large transmit signal before it encounters any nonlinear component. The second step employs signal processing to further suppress the residual transmit signal from the receive path. The results of applying this two-step approach are the plots in ***Figure 7***, which show measured T/R isolation at the signal processor output. The isolation is > 70 dB in both channels from 200 MHz to 3 GHz and > 80 dB in one of the channels up to 1 GHz. The isolation decreases above 3 GHz, but the minimum isolation of 54.9 dB at 5 GHz in one of the channels still easily exceeds the system's requirement of > 40 dB.

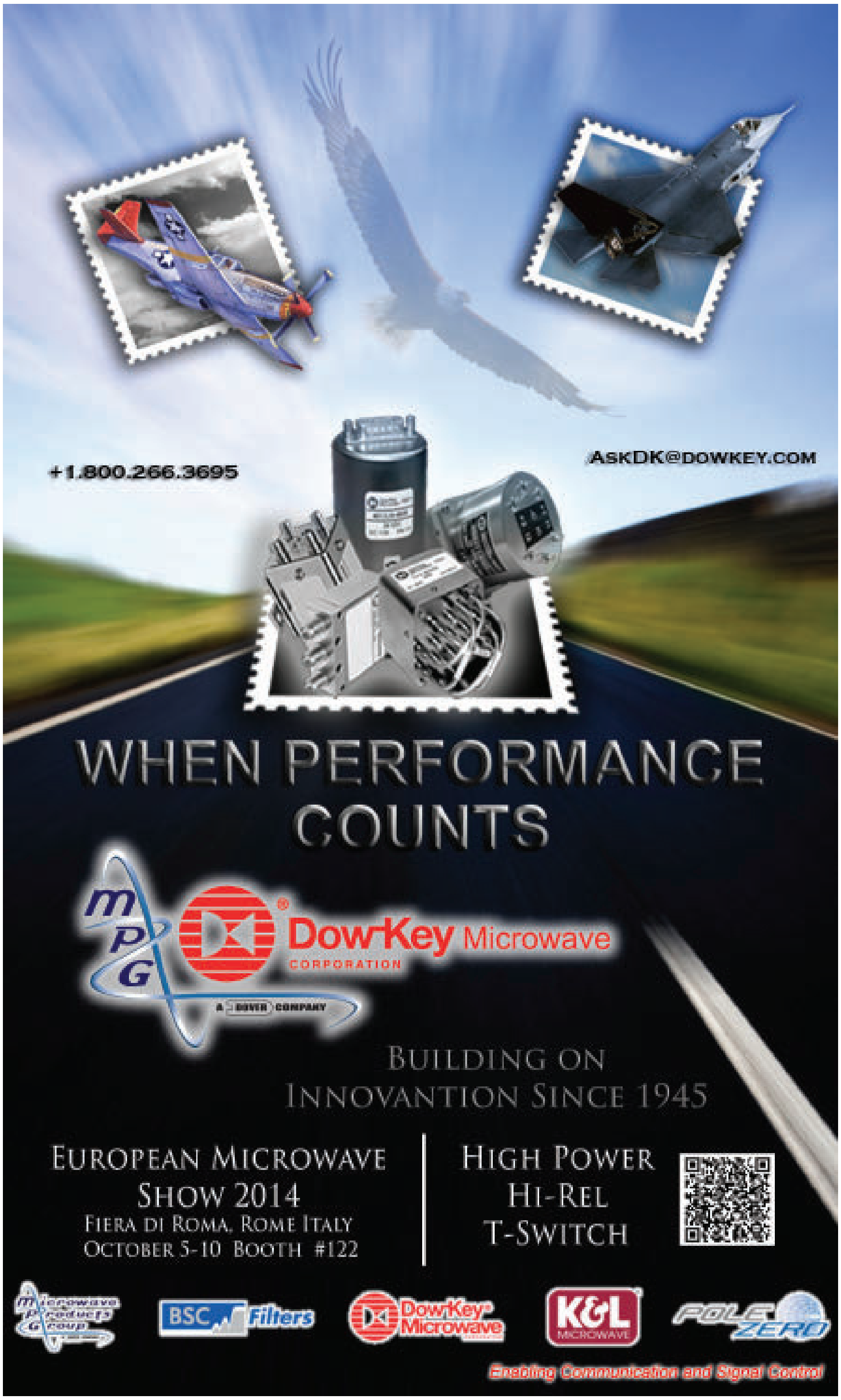


▲ *Fig. 7 Plot of T/R isolation versus frequency at the output of the signal processor.*

For applications requiring greater T/R isolation, further improvements can be made. It should be noted that the T/R results in Figure 7 are obtained with the TIRx connected to a customer provided antenna that has wide bandwidth, but a return loss of only 7 dB at some frequencies. Connecting an impedance that replicates this antenna's impedance to the antenna balance port on the TIRx enables roughly 20 dB of the T/R isolation to be achieved in the analog front end, placing the remainder of the burden on the signal processing. An important consequence of this is that the instantaneous bandwidth (IBW) over which the transmit signal is suppressed becomes dependent on the IBW of the signal processing hardware – e.g., the A/D converters and FPGA. In contrast, the IBW of the T/R isolation at the output of the TIRx itself is the full TIRx operating bandwidth, shown by the data plotted in Figure 1b, that will extend over decades.

CONCLUSION

This article describes technologies that enable full-duplex wireless communication by transmitting and receiving simultaneously on the same frequency through a single antenna. The key enabler is a unique RF front end device called the Transmit Isolating Receiver (TIRx) that takes the place of both a circulator and low



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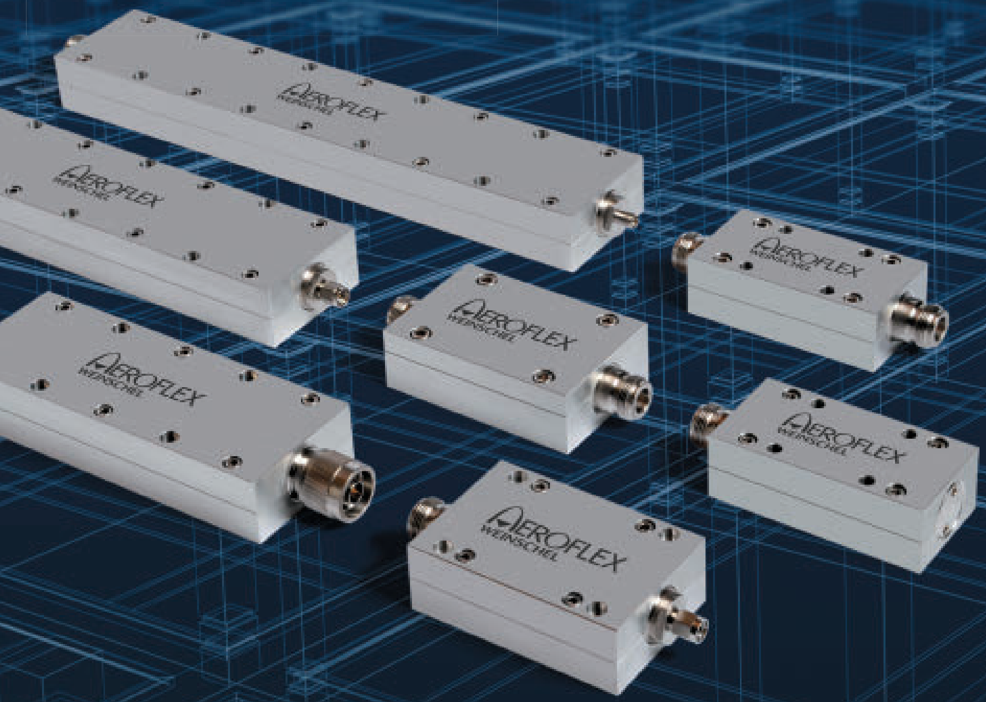

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Model	Frequency (GHz)	Avg. Power (W)	Peak Power (kW)	Available dB Values	SWR	Connector Type Available
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72	DC to 4.0	50	5	3, 6, 10, 20, 30	1.20	Type N
253	DC to 6.0	550	10	10, 20, 30, 40	1.10 to 1.20*	SMK (2.92mm) or N
257	DC to 6.0	250	10	10, 20, 30, 40	1.10	SMK (2.92mm) or N
258	DC to 6.0	400	10	10, 20, 30, 40	1.10 to 1.25*	SMK (2.92mm) or N
268	DC to 6.0	100	10	6, 10, 20, 30, 40	1.10 to 1.15*	SMK (2.92mm) or N
284	DC to 10.0	50	5	3, 6, 10, 20, 30, 40	1.10 to 1.30*	SMK (2.92mm) or N

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Model	Frequency (GHz)	Avg. Power (W)	Peak Power (kW)	SWR	Connector Type Available
1441	DC to 4.0	50	5	1.20	Type N
1470	DC to 6.0	100	10	1.20	SMK (2.92mm) or N
1471	DC to 6.0	250	10	1.20	SMK (2.92mm) or N
1472	DC to 6.0	400	10	1.20	SMK (2.92mm) or N
1473	DC to 6.0	400	10	1.20	SMK (2.92mm) or N
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ACKNOWLEDGMENT

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Charles H. Cox III, is the president and CEO of Photonic Systems Inc. (PSI). Prior to founding PSI, Cox was on the research staff at MIT and at Lincoln Laboratory; he received his ScD from MIT. Cox holds 10 U.S. patents, has given three plenary and 71 invited talks on RF/microwave photonics and has published more than 70 papers on his research in the field. He has written a textbook titled "Analog Optical Links," co-edited a book on milestone papers in photonics and written five book chapters. He is a fellow of IEEE and OSA. Cox served as a member of the Advisory Group on Electron Devices (AGED) from 2003 – 2009.

Edward I. Ackerman is vice president of research & development at Photonic Systems, Inc. (PSI). In addition to PSI, Ackerman's technology and product development experience includes work at GE Electronics Laboratory and MIT Lincoln Laboratory. Ackerman has co-edited a book and has authored or co-authored three book chapters as well as more than 50 technical papers on the subject of RF/microwave photonic subsystem performance modeling and optimization. Ackerman is a Fellow of the IEEE and holds seven U.S. patents.

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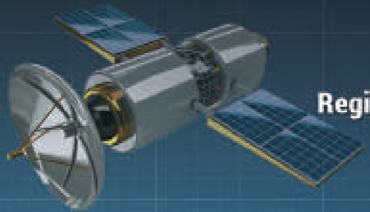

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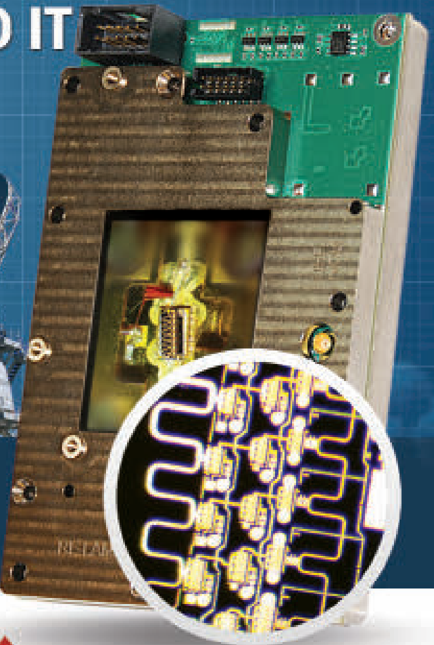

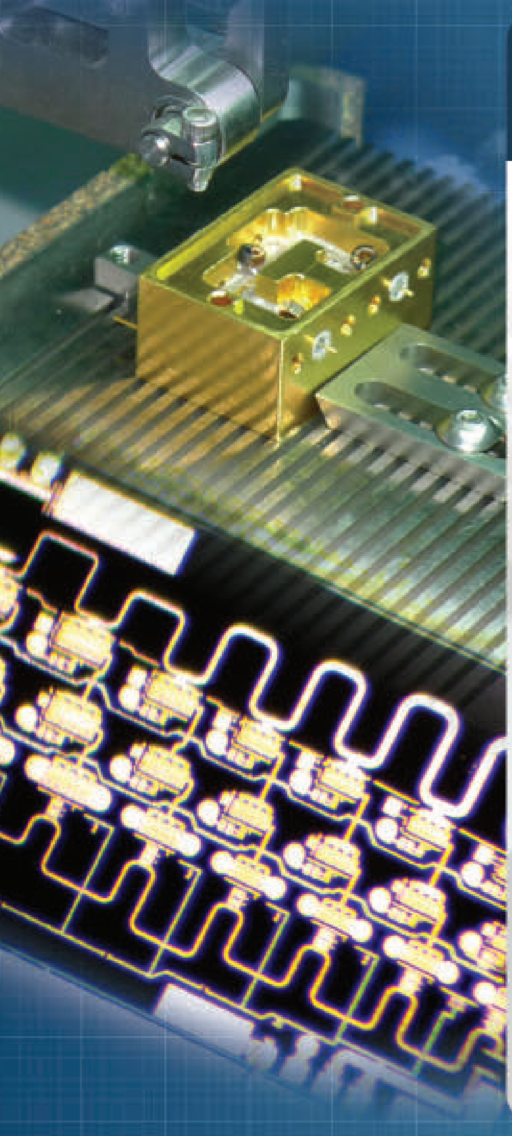

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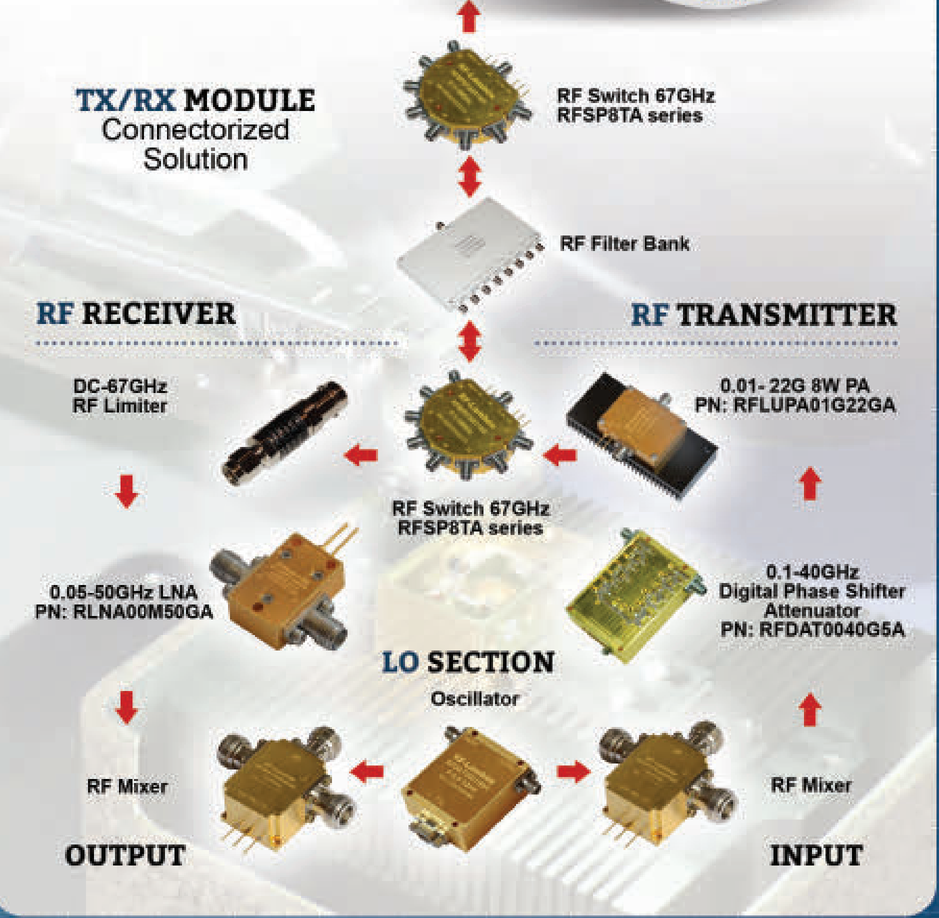

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Multi input, multi output (MIMO) antennas must provide higher quality mobile communication through diversity in RF signal transmission and reception. This challenges antenna designers to increase isolation between multiple antennas while reducing antenna size. A number of MIMO antennas were prototyped by Mak et al.,[1] with a feature of trapping the undesirable interaction between one element and the other, imitating a closed current loop suppressing a long current flow. The radiation patterns and isolation are acceptable, but the structure is physically large, occupying the top edge and two sides of the handset device. K. Payandehjoo et al.,[2] utilized an electromagnetic band gap (EBG) structure to increase diversity gain by weakening the coupling between two antennas; however, the structure is large and the frequency is outside the WiMAX band. Wang, et al.,[3] demonstrated two microstrip fed antennas having the layered and vertical parts of the radiators perpendicular to the layered ground by periodically meandering a decoupling element for better isolation. Although isolation is greater than 12 dB, the structure uses a microstrip fed monopole-type decoupling element occupying a large volume. Simple meandered quarter-wave long radiators are separated by a split ground and a hybrid coupler by Sharawi et al.,[4] and Bhatti et al.,[5] respectively. The radiators are connected in the LC-based branch coupler for lower cou-

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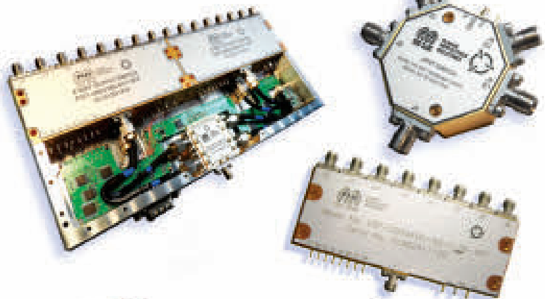

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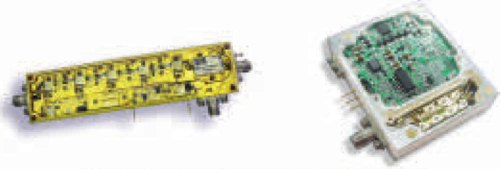

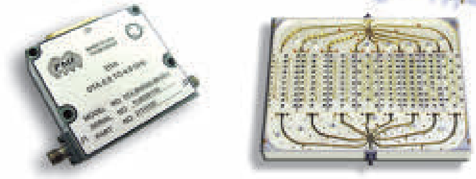

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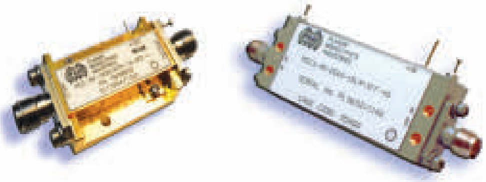

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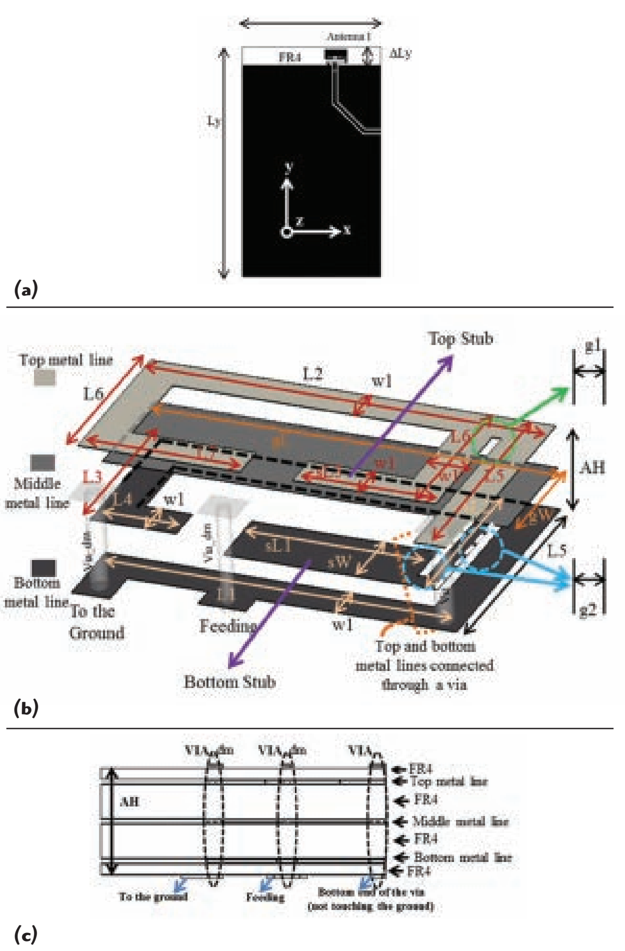
Hermetic Sealing, High Reliability to Mil-Std-883, Small Quantity Requirements accepted & we offer Custom Designs too pling,[5] but 3D folded monopoles share a shorted loop for better decoupling.[6] A very compact radiator using a ZOR split ring resonator (SRR) is proposed and adopted for miniature symmetric MIMO antennas by S. Yoo et al.[7] It occupies two-thirds of the top edge of a handset device, with a gain larger than 2 dBi and isolation of over 12 dB.

This article describes a compact bandwidth-widened and high-isolation MIMO antenna for LTE mobile communication designed to meet the specifications in ***Table 1***. It utilizes a small 0.034λ_g radiator, similar to that described by Yoo et al., but with the addition of four thin FR4 layers to generate closely located resonances for broader bandwidth. The radiator design is applied to radiating elements one and two on the top-edge of a handheld MIMO device with the entire length equal to 0.108λ_g. In contrast to the other antennas designed for a similar frequency band that usually occupy a large proportion of the upper edge area of the ground; this one, in the form of a thin layered structure, has a length less than 1/6.5 Wx (see ***Figure 1***).

TABLE I

DESIGN SPECIFICATIONS

Item	Specification	Item	Specification
f_0, BW	2.5 GHz, ≥ 250 MHz	Return Loss	$\|S_{11}\|\leq$-10 dB
Gain	≥ 0 dBi	Isolation	$\|S_{21}\|\leq$-10 dB
Efficiency	≥30%	Size	<0.25λ_g

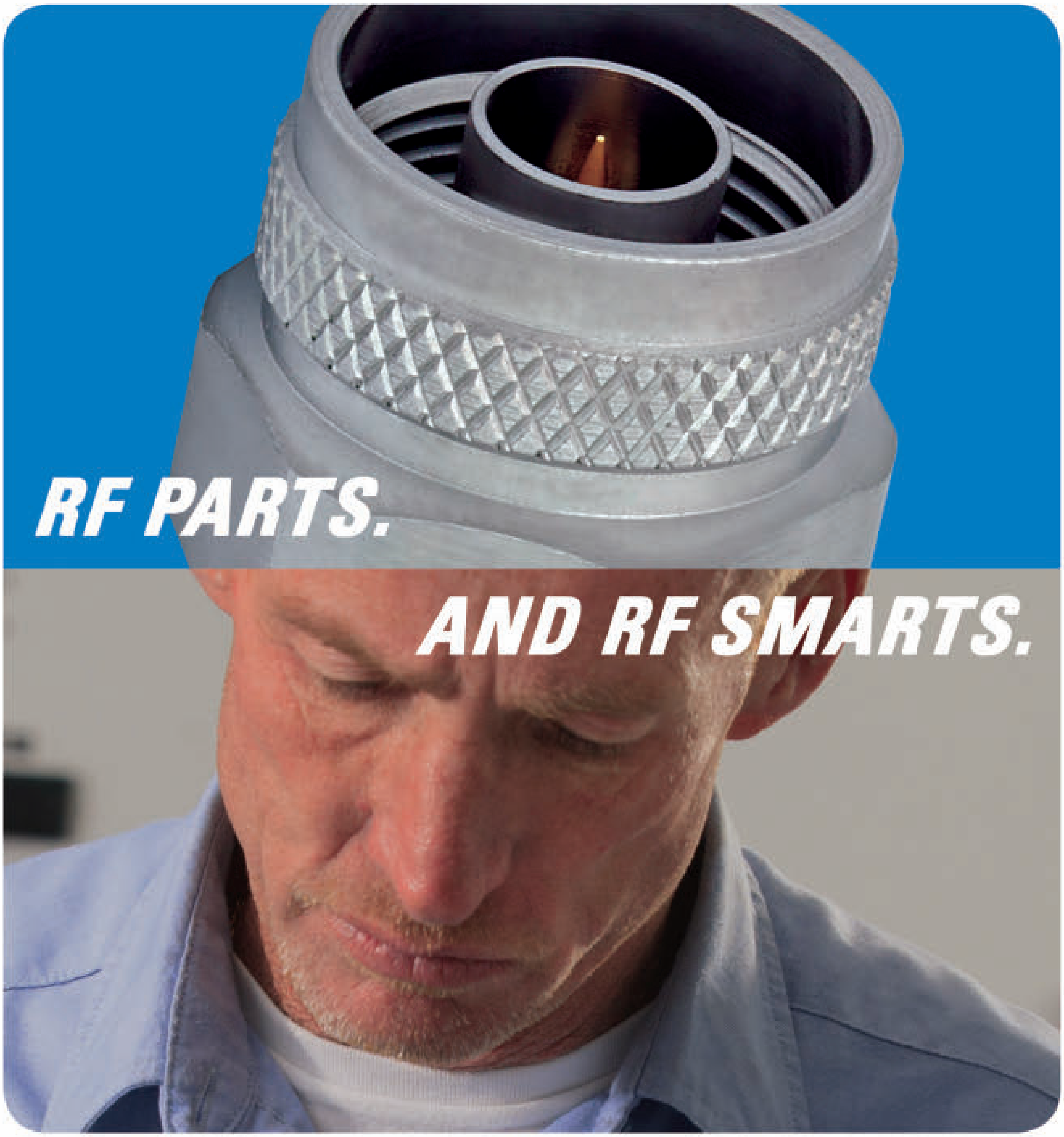


▲ *Fig. 1 Geometry of the radiating element attached to the ground; top overall view (a), 3D view of the radiating element (b), side-view showing the thin layers (c).*

ANTENNA ELEMENT DESIGN

The radiating element includes a pair of split ring resonators (SRR) as described by Yoo, but they are on different layers to induce resonance at closely located frequencies near 2.5 GHz for widening the bandwidth, and to align and gather the flux of the electric field in one direction through the layers for achieving a satisfactory antenna gain using the ZOR phenomenon. The platform including the ground in ***Figure 1a*** has dimensions Wx=53 mm, Ly=88 mm, and ΔLy=7 mm.

The antenna element attached to the ground and feed points has a volume L2×L5×AH = 8.5 × 6 × 2.3 mm = 117.3 mm^3. Confined to this volume, are two resonant current paths. The shorter one (bottom metal line or bottom SRR) corresponds to the higher resonant frequency and the longer one (top metal line or top SRR)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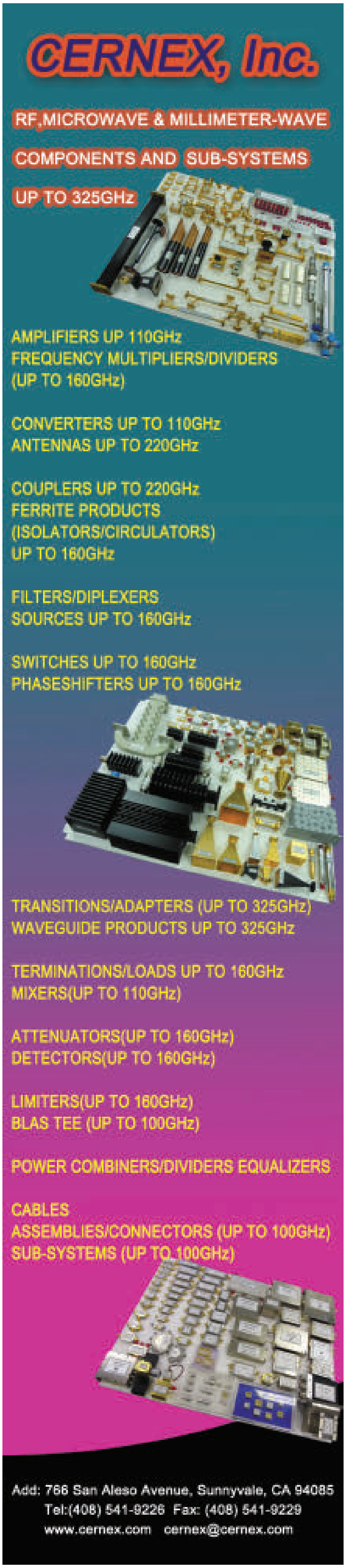

corresponds to the lower resonant frequency. As shown in ***Figure 1b***, the main part of the shorter resonance path is the cascade of L1, L5, L2, L3, and L4, while the longer path consists of L1, L5, L2, L6, and L7, with the via connecting the top and bottom metal lines. The other vias, for example Via_dm near the shorting point and Via_dm near the feed, have no electrical function but are there for remanufacturing purposes.

Because the top and bottom SRRs are separated by two FR4 layers, as shown in ***Figure 1c***, which might result in a weak interaction, the middle metal line (gL × gW) is inserted to strengthen the coupling. Stubs are included in the top and bottom metal lines to control the coupling as well as the resonance lengths. Parametric studies are used to determine the structure's physical dimensions for alignment of the two resonant frequencies just above and below 2.5 GHz.

The bottom metal line with L4 varied from 1 through 2 mm controls the high frequency resonance as shown in ***Figure 2a***. The low frequency resonance is changed by the top metal line with L7 ranging from 1 through 2.5 mm as shown in ***Figure 2b***. After several parametric sweeps the dimensions of 13.5, 6, 2.3 mm, 6.9, 8.5, 2, 1, 5.15, 2.8, 1.8, 0.8, 0.2, 0.2, 2.5, and 8.5 mm are chosen for AL, AW, AH, L1, L2, L3, L4, L5, L6, L7, w1, g1, g2, gW, and gL, respectively. All the dielectric materials are FR4 with ε_r= 4.3 and loss tangent of 0.02.

Due to the strength of the two resonances and the distance between them, there are at this point, two narrow bands instead of one wide band. This is corrected with the addition of the top and bottom stubs and the adjustment of lengths sL1, sL2 and sL3. As the length of the bottom stub (bottom SRR) grows, the high frequency resonance moves downward from 2.63 to 2.6 GHz. Also, as the top stub is trimmed to increase coupling with the bottom metal line, the low frequency resonance becomes slightly weaker and its steep curve becomes smoother. This is observed in ***Figure 2c*** as the introduction and adjustment of the stubs moves the split resonant frequencies closer and the bandwidth becomes wider. The dimensions 3.9, 2.9, and 3 mm are chosen for sL1, sL2, and sL3, respectively. As shown in Figure 2c, the bandwidth is marginally greater than 250 MHz. This is further adjusted and finalized in tuning of the the two-element MIMO antenna design.

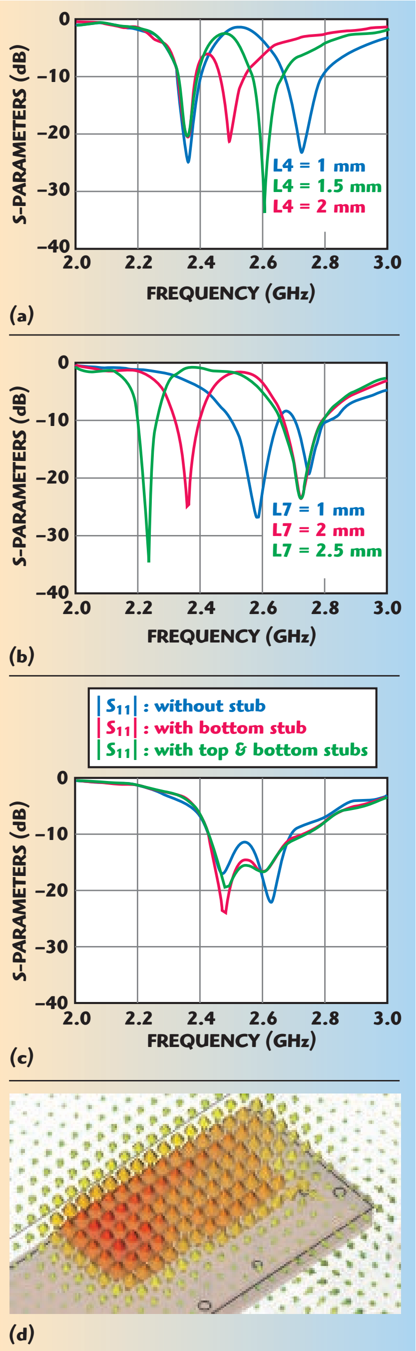

Fig. 2 *$|S_{11}|$ versus L4 for the high frequency resonance (a), $|S_{11}|$ versus L7 for the low frequency resonance (b), $|S_{11}|$ versus stub length (c), ZOR electric field distribution (d).*

Besides return loss, the ZOR phenomenon provides another beneficial characteristic. As expected, the in-phase and dense flux of the electric field is generated in the frequency

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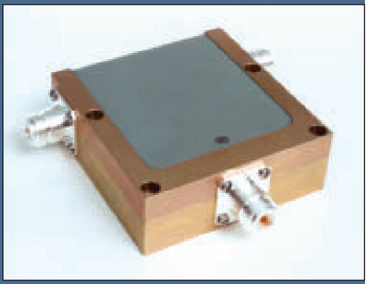

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CT-3838-N	5 Kw Pk 500 W Av	N Conn.	2.7–3.1 GHz
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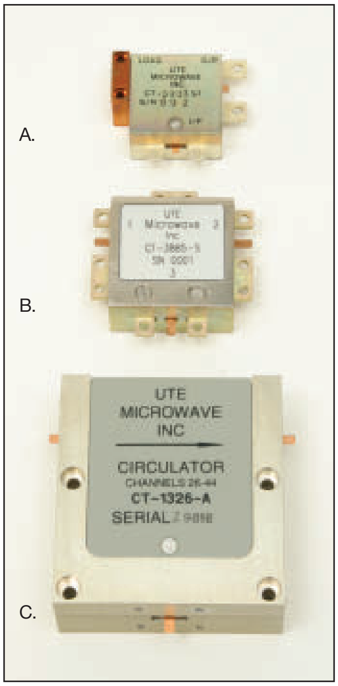

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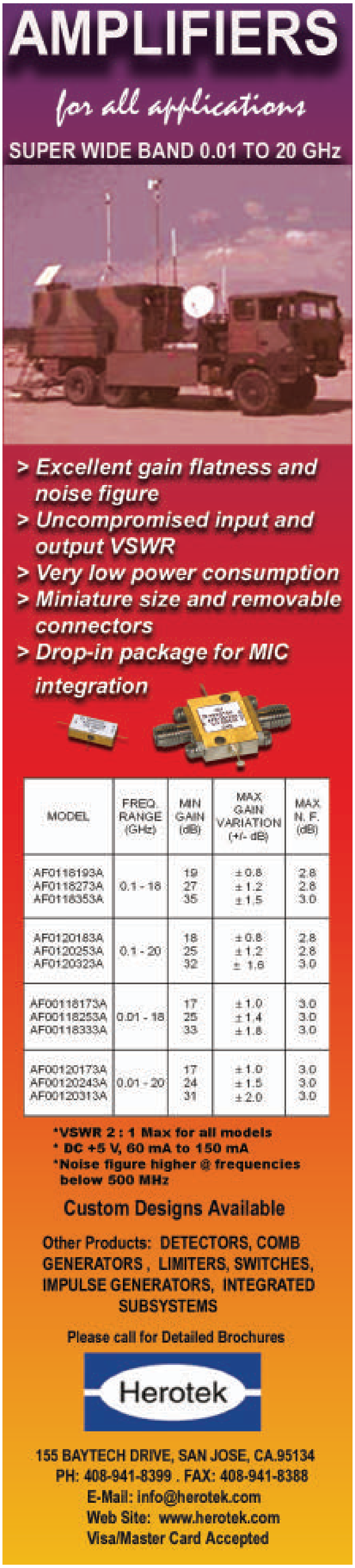
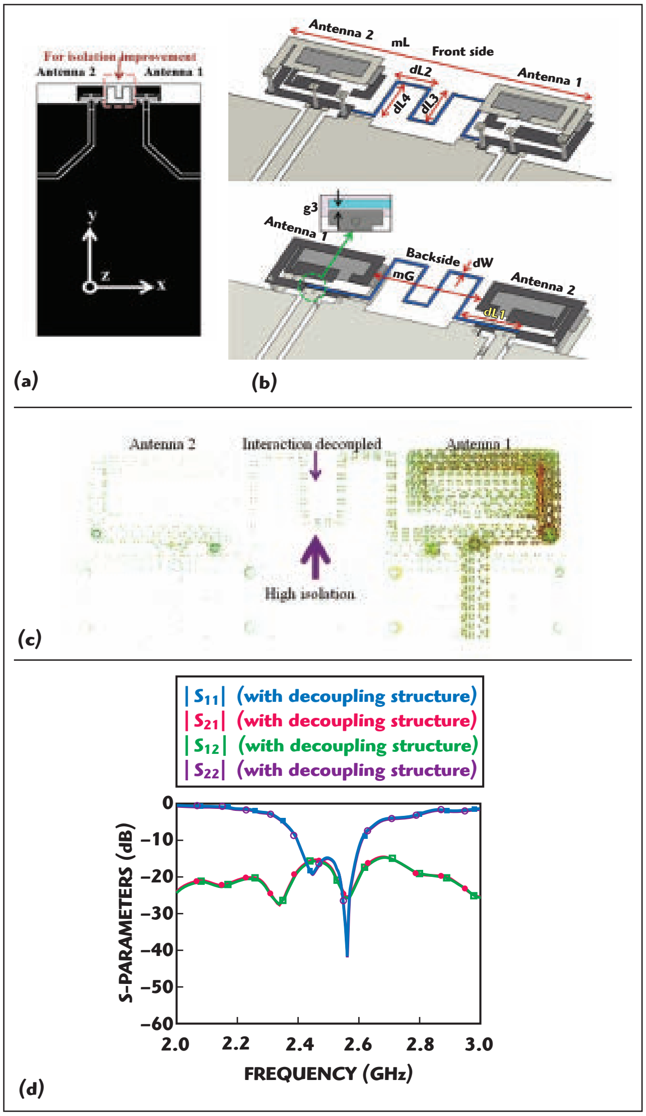


band, as shown in ***Figure 2d***. This is instrumental in producing an antenna gain over 0 dBi in a compact radiating structure as short as $0.034\lambda_g$.

COMPACT MIMO ANTENNA WITH HIGH ISOLATION

Due to its substantial size reduction, the antenna element design can be expanded to applications requiring multiple antennas (e.g. mobile phones) in a limited space. ***Figure 3a*** shows a MIMO antenna with the two compact radiating elements connected through a folded line. In ***Figure 3b***, the folded line serves as a decoupler, inspired by a magnetic wall. Coupling to the antennas is through gaps (g3) so as not to affect their previously determined physical dimensions. The initial value of L7 alone changes from 1.8 to 2 mm. With mL, mW, mG, g3, dW, dL1, dL2, dL3, and dL4 equal to 27, 6, 10, 0.1, 0.3, 5.7, 2.6, 3.95, and 4.55 mm as, respectively, the folded line almost suppresses coupling between the antennas, as shown in ***Figure 3c***. Also, the full-wave simulated S_{11} and S_{21} meet the required BW, f_o and isolation as shown in ***Figure 3d***. Now, the structure is fabricated and its performance is test for validation.

Figure 4a shows that measured S_{11} and S_{21} agree well with simulation and are in compliance with design specifications in Table 1. Measured far-field patterns, plotted in ***Figure 4b***, show good agreement with predictions, achieving a gain ≥ 1.5 dBi and efficiency ≥ 40 percent averaged over the bandwidth, suitable for mobile communication.



▲ *Fig. 3 MIMO antenna; top view (a), front and backside expanded view (b), isolation image (c), simulated $|S_{11}|$ and $|S_{21}|$ (d).*

CONCLUSION

Using a small radiating structure as its basis, a novel compact ZOR MIMO antenna with enhanced bandwidth and high isolation has been designed. Its total length of less than $0.11\lambda_g$ and its performance makes it suitable for mobile LTE communication applications. ■

ACKNOWLEDGMENT

This work was supported by the Research Grant of Incheon National University with S. Kahng as the lead-author and in collaboration with LG Innotek Co. Ltd.

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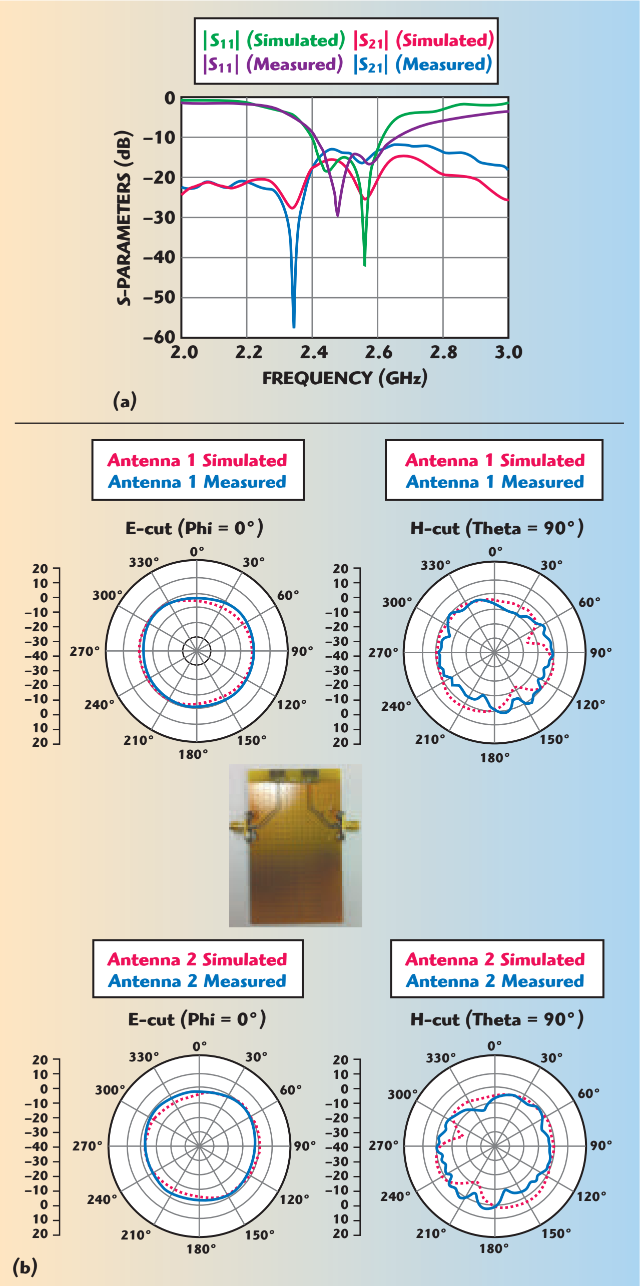

▲ *Fig. 4 Measured $|S_{11}|$ and $|S_{21}|$ (a), photo and beam patterns of antennas 1 and 2 (b).*

Kyungseok Kahng *received his B.E. in 2012 and is currently studying for his M.E. at the Incheon National University, Incheon, Korea. His research fields are microwave engineering, RF components, antennas, radar and metamaterials.*

Sungtek Kahng *received his Ph.D. in electronics and communication engineering from Hanyang University, Korea in 2000, with a specialty in radio science and engineering. From 2000 to early 2004, he worked for the Electronics and Telecommunication Research Institute on numerical electromagnetic characterization and developed RF passive components for satellites. In March 2004, he joined the Department of Information and Telecommunication Engineering at the University of Incheon where he has continued research on analysis and advanced design methods of microwave components and antennas, including metamaterial technologies, MIMO communication, and wireless power transfer for M2M/cyber-physical systems.*

Inkyu Yang *received his B.E. in 2012 and is currently studying for his M.E. at the Incheon National University, Incheon, Korea. His research fields are microwave engineering, RF components, antennas, wireless power transfer and metamaterials.*

Qun Wu *received his B.S. in radio engineering, his M.E. in electromagnetic fields and microwave technology, and his Ph.D. in communication and information systems engineering, all at Harbin Institute of Technology, Harbin, China, in 1977, 1988, and 1999, respectively. Since 1990, he has been a professor with the Department of Electronic and communication Engineering at HIT, China.*

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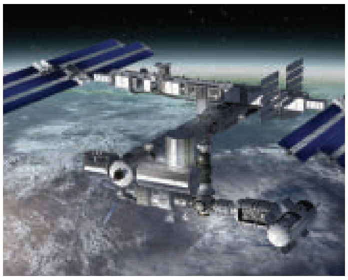

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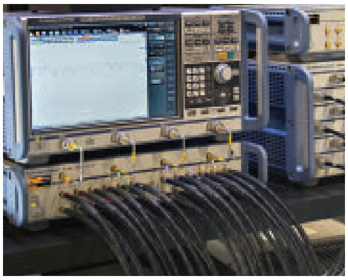

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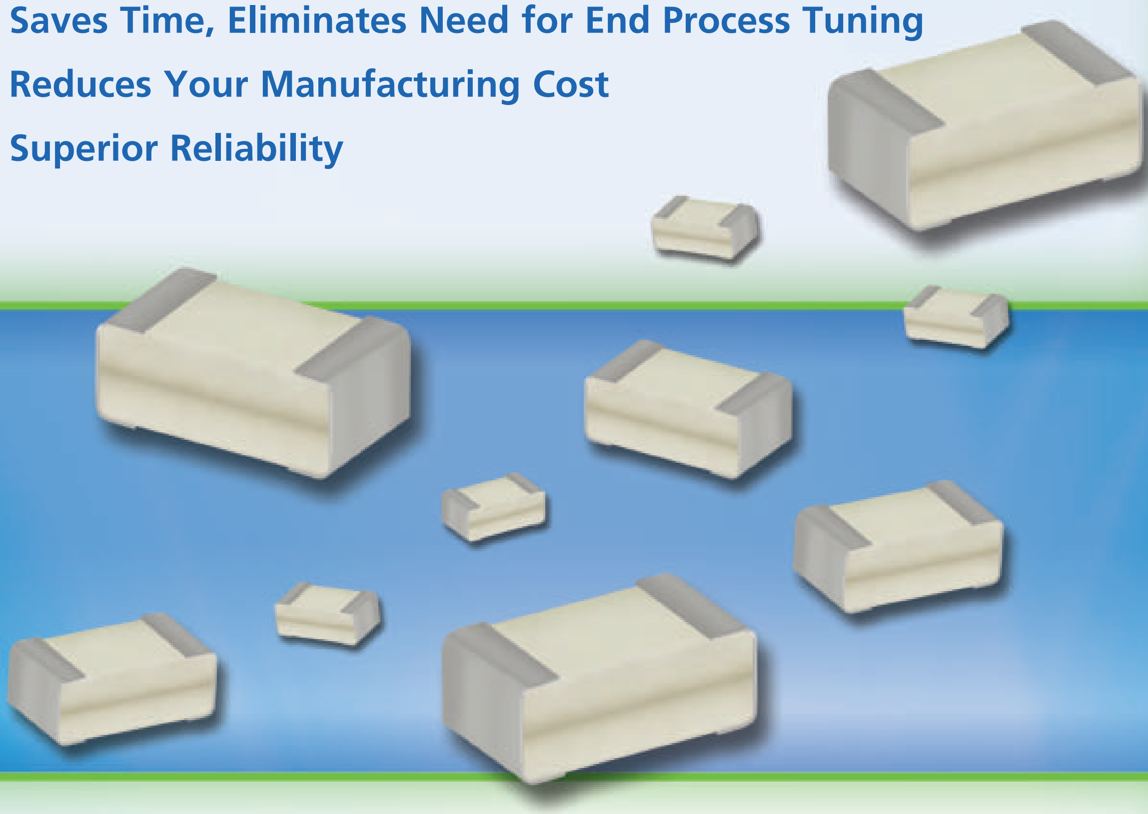
6 to 26 GHz Detectors for High Data Rate ASK Signal Demodulation

X. Feng, Y.H. Zhang, W. Xue, H. Zhang and Y. Fan
University of Electronic Science and Technology of China, Chengdu, China

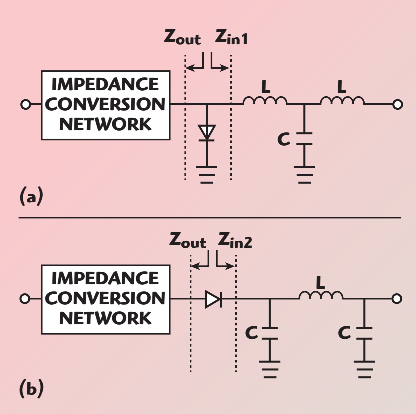
Ultra wideband detectors developed with flat responses for high data rate ASK demodulation contain three blocks; an impedance conversion network (ICN), a diode and a lowpass filter (LPF). Wideband properties are achieved by designing the LPF to have a suitable input impedance in the stopband; and, high data rate capabilities are achieved by designing the ICN to have an appropriate output impedance at baseband frequencies. The ICN is also tuned by EDA tools to obtain a flat response. Measurements show narrowband fluctuations within 1 GHz of better than 1.07 dB in a 6 to 26 GHz band. The designed demodulation rate is 2.5 Gbps.

Detectors are used in microwave and millimeter wave circuits and systems to perform various functions such as power detection and signal demodulation.[1] For demodulation, systems often employ amplitude shift keying (ASK), which is simple and capable of high data rates. Unlike detectors with high load impedances used for power detection or even low data rate demodulation, high data rate demodulation detectors usually require 50 Ω load impedances to facilitate post amplification.

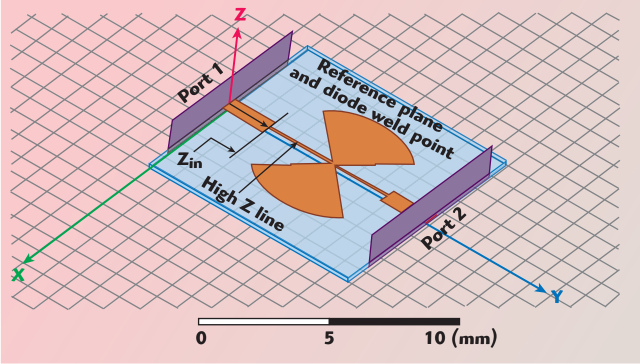
For communication circuit engineers, research on demodulation detectors is still an active area; especially for optical, UWB or millimeter wave communication system applications.[2-6] A square-law demodulator developed for ASK/FSK heterodyne optical receivers was reported by Ghiggino[2] with a data rate of 648 Mbps in the operating band of 1 to 4 GHz. The detector developed by Ko et al.,[3] is based on a schottky-barrier-diode (SBD) and is used for a 60 GHz ASK system with bandwidth of 3 GHz with a 622 Mbps data transmission rate. Zirath and He[4] introduced an active detector based on an mHEMT with a 300 Mbps data rate and a flat working bandwidth of 10 GHz and a ~60 GHz center frequency. The above three detectors feature high demodulation rates but narrow relative bandwidths. An AM detector for UWB (3 to 10 GHz) communication system is reported by Sankaran and O,[5] however, its verified baseband data rate is only 700 kbps. A broadband envelope detector based on a com~mercially available GaAs packaged diode is demonstrated to work over a 2 to 8 GHz band,[6] but both total fluctuation and narrowband fluctuation are high (7.5 dB), which hampers subsequent signal processing. These two detectors have wide working bandwidths but suffer from either low data rates or fluctuant responses.



▲ *Fig. 1 Conventional detector.*



▲ *Fig. 2 Two detector configurations; shunt (a), series (b).*



▲ *Fig. 3 Microstrip realization of a LPF for the shunt detector.*

In this article, two detector configurations (shunt and series) are described. Both feature a wide working bandwidth, a flat response and a high data rate. An LPF is analyzed and designed to have a wide suppression band and an input impedance that enables the detector's wideband property. An ICN replaces the matching network used in conventional detectors to provide a flat response and high data rate demodulation.

DESIGN PROCEDURE

Circuit Configuration

Although the application may vary, a conventional detector usually consists of an input matching network, a core detection unit (e.g. diode or FET) and an output lowpass filter (see ***Figure 1***). The output of a demodulation detector is different from a power detector because it is not DC, but is a baseband signal that is passed by a DC blocking capacitor.

Matching to achieve a wide RF operating band is difficult. To address this problem, the conventional input matching network is replaced with an ICN. The ICN provides a flat wide band response and an impedance at baseband frequencies that enables high data rates.

The diode provides nonlinearity to generate new frequency components, including DC and higher order harmonics, or the baseband component for an ASK signal input.[1] There are two circuit configurations, i.e. shunt and series (see ***Figure 2***). Both are built and tested to illustrate the effect of the LPF's input impedance on IF bandwidth and to compare overall performance. The first function of the LPF is to select the desired IF signal generated by the diode and keep the RF frequency and higher order harmonics from reaching the output port.[7] The second function is to concentrate RF energy on the diode in order to more efficiently utilize its nonlinearity.

Low Pass Filter Analysis and Design

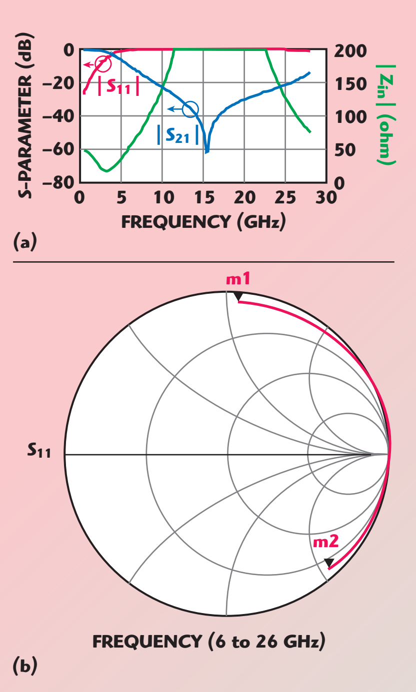
The LPF has a passband and stopband, the passband is matched to a reference impedance (usually 50 Ω), and the stopband is, ideally, either open or short (this is true for any filter). The LPF in ***Figure 2a,*** for example, approaches an open circuit in its stopband, so S_{11} on the Smith Chart is very close to the right, whereas S_{11} for the LPF in ***Figure 2b*** approaches a short on the opposite side. LPFs that simply produce wide stopbands, without considering input impedance, are inadequate for this detector design, because RF energy concentration is dependent upon the LPF's input impedance in the stopband. This is seldom discussed in the literature.[8-10]

For the shunt detector, it can be deduced that if the input impedance of the LPF is larger than that of the diode, more RF energy is added to the diode, therefore, the LPF should present a high input impedance in the stopband. Conversely, a low impedance in the stopband will cause a decrease in RF energy added to the diode and hence a decreased working bandwidth. Consider the input impedance of the third-order lumped LPF in Figure 2a:

$$Z_{in1} = j\omega L + \frac{1}{j\omega C} \| \left(j\omega L + 50 \right) \approx j\omega L \quad (1)$$

where ω is the angular frequency and it is assumed to be in the stopband, such that jωL and jωC both have very large values. Thus, Z_{in1} is an inductive high impedance, which features an open stopband property and satisfies the requirement discussed above. In microstrip, a high impedance line (narrow width) is used to realize a series inductor (see ***Figure 3***).

In practice, it is difficult to maintain a high Z_{in} for the microstrip LPF in Figure 3 over a wide stopband. This may be addressed by restricting the length or the order of the filter. Although high order (implying large size and length) provides excellent suppression, it also introduces parasitics so that a high impedance line or radial stub cannot be simply treated as a series inductor or shunt capacitor,



▲ *Fig. 4 Simulated S-parameters for the shunt detector LPF; S-parameter amplitude and Z_{in} magnitude (a), phase of S_{11} related to Z_{in} (b).*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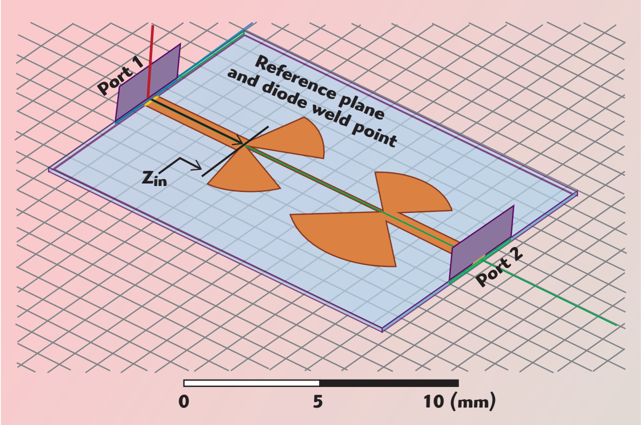


▲ *Fig. 5 Microstrip realization of an LPF for the series detector.*

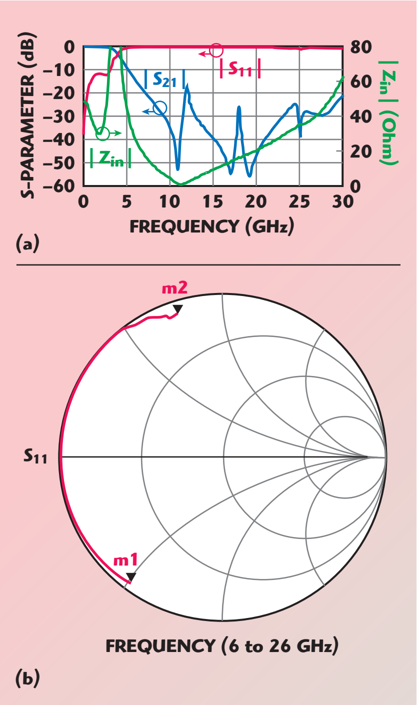
respectively, and the property of Z_{in} changes with frequency. Examples of LPF designs in the literature[8-10] have frequency dependent stopband properties, i.e. S_{11} phase moves from one side of the Smith Chart to another. To reach an acceptable compromise between bandwidth and suppression, no higher than third-order is chosen.

Figure 4 shows the simulated results of the shunt LPF. Port 1 is shifted to the reference plane where Z_{in} is calculated. ***Figure 4b*** shows that S_{11} falls on the right side of the Smith Chart, which means the magnitude of its input impedance $|Z_{in}|$ is larger than 50 Ω. The closer it is to the right endpoint, the larger the impedance. $|S_{21}|$, which is better than -10 dB from 6 to 26 GHz, shows that good suppression is simultaneously achieved.

For the series detector, the input impedance must be low to ensure that RF energy is concentrated on the diode. Consider the third-order lumped filter shown in Figure 2b:

$$Z_{in2} = \frac{1}{j\omega C} \| \left(j\omega L + \frac{1}{j\omega C} \| 50 \right) \approx \frac{1}{j\omega C} \qquad (2)$$

where ω is also assumed to be in stopband. Thus Z_{in2} is a capacitive low impedance, which features low impedance stopband properties. In microstrip, a shunt radial stub is used to realize a shunt capacitor (see ***Figure 5***). ***Figure 6*** shows the simulation results for the series LPF. S_{11} is on the left side of the Smith Chart, which means $|Z_{in}|$ is smaller than 50 Ω. $|S_{21}|$ is better than -15 dB from 6 to 26 GHz.



▲ *Fig. 6 Simulated S-parameters for the series detector LPF; S-parameter amplitude and Z_{in} magnitude (a), phase of S_{11} related to Z_{in} (b).*

Although suppression of 10 or 15 dB is not as good some LPFs with wide and deep suppression bands,[8-10] they do not consider the input impedance or phase of S_{11}. It is necessary to consider not only suppression but also input impedance in the stopband when designing a wideband detector or other wideband devices like mixers. The two LPFs described in this article have input impedances that focus more RF energy on the diode and utilize its nonlinearity more efficiently, resulting in higher sensitivity and wider working bands.

Impedance Conversion Network Design

Conventionally, the diode's input impedance is often matched to 50 Ω over a narrow RF frequency band in order to obtain a high output voltage. As shown in ***Figure 7***, this is because the input impedance of the diode at different frequencies is dispersed across the Smith Chart far away from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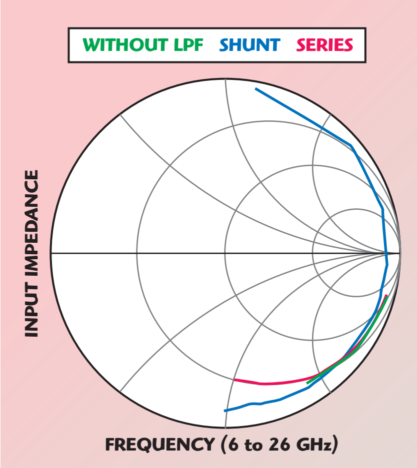


Fig. 7 Diode input impedance for different configurations.

the center, making wideband matching difficult to achieve. In this design, sensitivity is traded for flatness, by replacing the matching network with an ICN. In order to demodulate a high bit rate ASK signal, the ICN must convert 50 Ω to an appropriate impedance as seen from the diode to the network at baseband frequencies.

A high impedance must be presented at baseband frequencies to the shunt type detector. As shown in ***Figure 8***, a simplified baseband equivalent circuit (ignoring reactive elements) is a current source with two parallel resistors, one representing the output load (R_L) and the other representing the magnitude of the input impedance looking into the ICN ($|Z_{out}|$). The larger $|Z_{out}|$ relative to R_L, the more baseband energy is transmitted to the load.

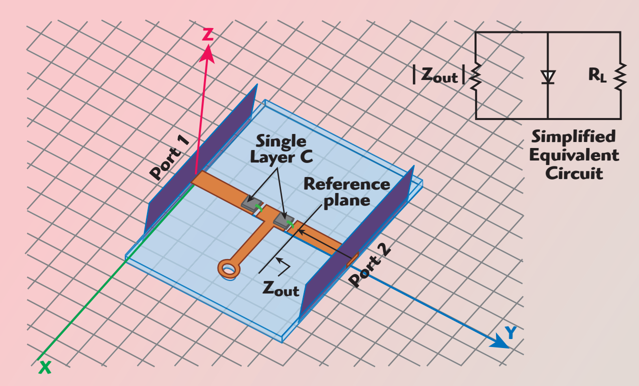


Fig. 8 ICN for the shunt detector along with simplified equivalent circuit.

A three order half lumped element microstrip high-pass filter (HPF) is designed to realize the ICN for the shunt type detector. 'Half lumped' means that the HPF is composed of both distributed and lumped elements. The lumped elements are two single layer capacitors, because it is difficult to attain enough capacitance using distributed techniques.

The simulated results (an HPF response) are shown in ***Figure 9***. Figure 9b shows that the magnitude of the output impedance is converted from 50 Ω (source impedance) to a larger value in the baseband (e.g. 80 Ω at 2 GHz). In the RF band, the output impedance is around 50 Ω, which does not match the diode input impedance (generally not 50 Ω). This mismatching method is frequently used in wideband design, because there is always a trade-off between match and bandwidth. An additional attenuator may be introduced between the source and detector to reduce the effect of unmatched energy on source.

For the series detector, in which diode

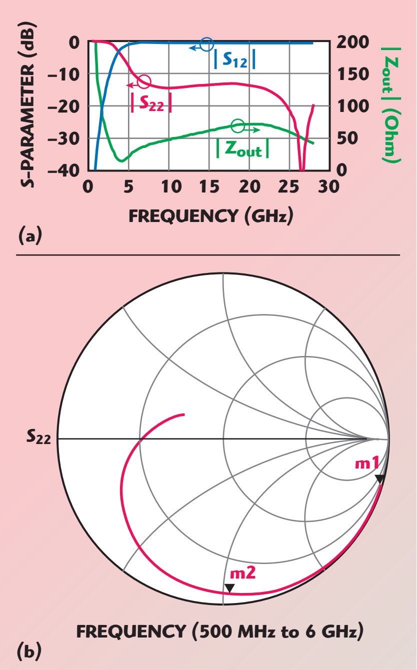
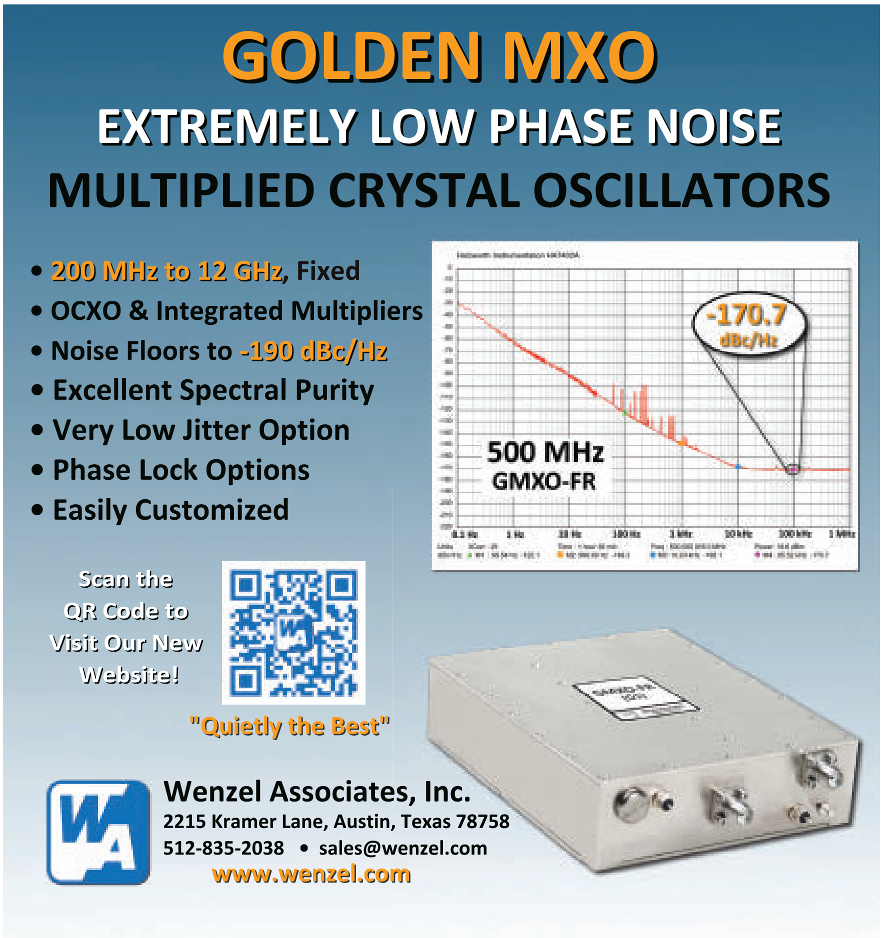
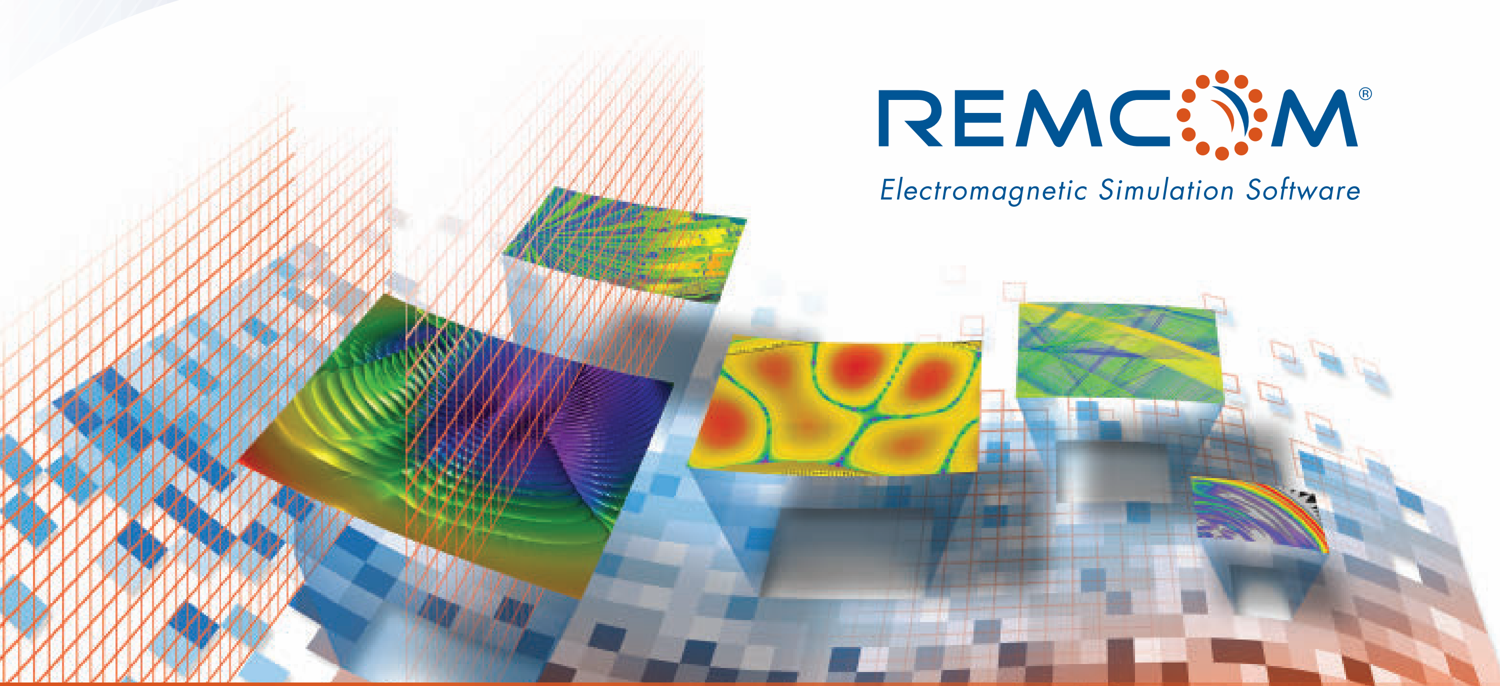
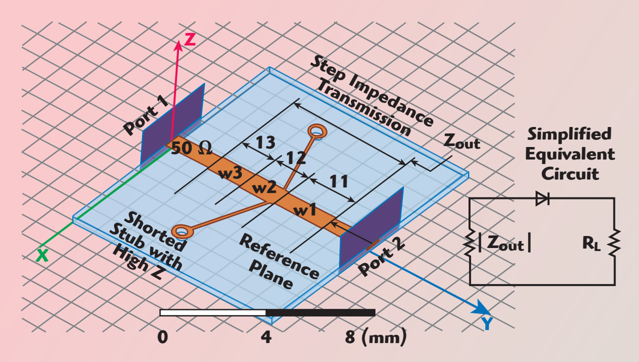


Fig. 9 Simulated S-parameters for the shunt detector ICN; S-parameter amplitude and Z_{out} magnitude (a), phase of S_{22} related to Z_{out} (b).







▲ *Fig. 10 ICN for the series detector along with simplified equivalent circuit.*

bridges over the ICN and LPF, a low impedance must be presented in the baseband. A simplified baseband equivalent circuit (see ***Figure 10***) is a voltage source cascaded with $|Z_{out}|$ and R_L. The smaller $|Z_{out}|$ is relative to R_L, the more baseband energy is transmitted to the load.

The ICN for the series type detector consists of three sections of stepped impedance transmission line and a high RF impedance shorted stub in parallel at the end of the second section. The stub provides a DC path for the series diode and low impedance at baseband.

The simulation results are shown in ***Figure 11***. This ICN converts the magnitude of the output impedance from 50 Ω (source impedance) to a smaller value in baseband (e.g. 24 Ω at 2.5 GHz). In the RF band, the three sections of stepped impedance are optimized for a flat response of baseband output with the aid of EDA tools.

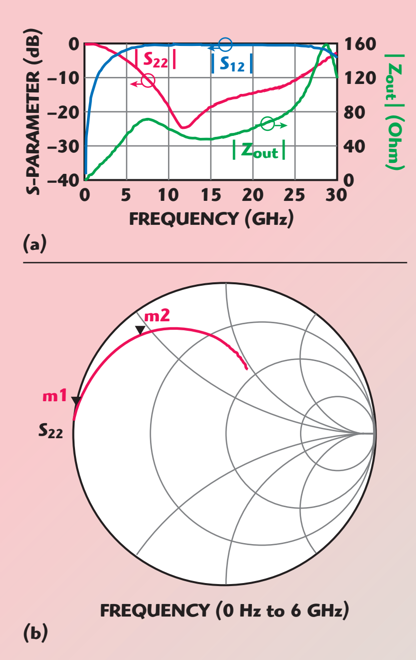
TOTAL CIRCUIT SIMULATION

The simulated DC output of the two detectors is shown in ***Figure 12***. RF excitation is -5 dBm from 0.1 to 28 GHz, and the load termination is 50 Ω. Total fluctuation F and narrow band fluctuation F' within 1 GHz are defined as follows:

$$F = 10\log\left(V_{max} / V_{min}\right) \qquad (3)$$

$$F'(x) = \max \left|10\log\left[V\left(x \pm 1\,GHz / V(x)\right)\right]\right|, \quad x = 7 \sim 25\,GHz \qquad (4)$$

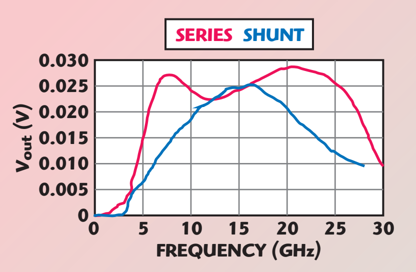
For the shunt detector, in the working band of 6 to 26 GHz, the maximum and minimum outputs



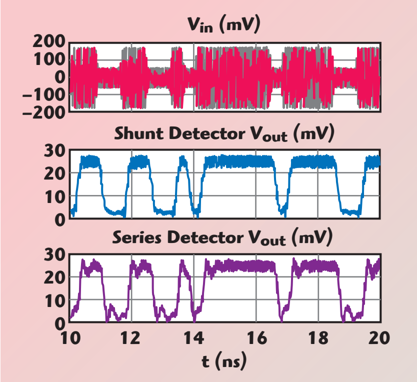
▲ *Fig. 11 Simulated S-parameters for the series detector ICN; S-parameter amplitude and Z_{out} magnitude (a), phase of S_{22} related to Z_{out} (b).*


GHz

are 25 and 8 mV, so that F = 4.9 dB. The worst $F'(x)$ = 1.094 dB when x = 7 GHz. For the series detector, F = 1.061 dB appears between outputs of 28 and 22 mV. The worst $F'(x)$ = 0.7 dB when x = 7 GHz.

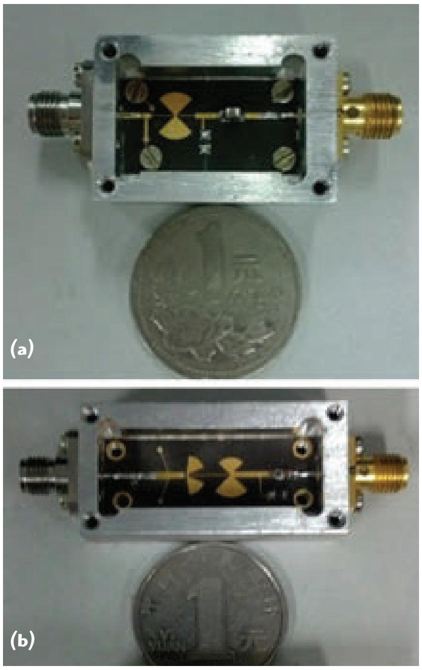


▲ *Fig. 12 Simulated detector output (Excitation: –5 dBm; load: 50 Ω).*



▲ *Fig. 13 Simulated demodulation waveform (2.5 Gbps).*

As a rule of thumb, a pseudo random binary sequence (PRBS) digital signal with bit rate of x Gbps covers x GHz spectrum. The passband of the LPF is designed to be 4 GHz, so the two detectors can work up to a 2.5 Gbps baseband signal rate. A simulated demodulation waveform is shown in ***Figure 13***, in which the carrier frequency is 16 GHz.

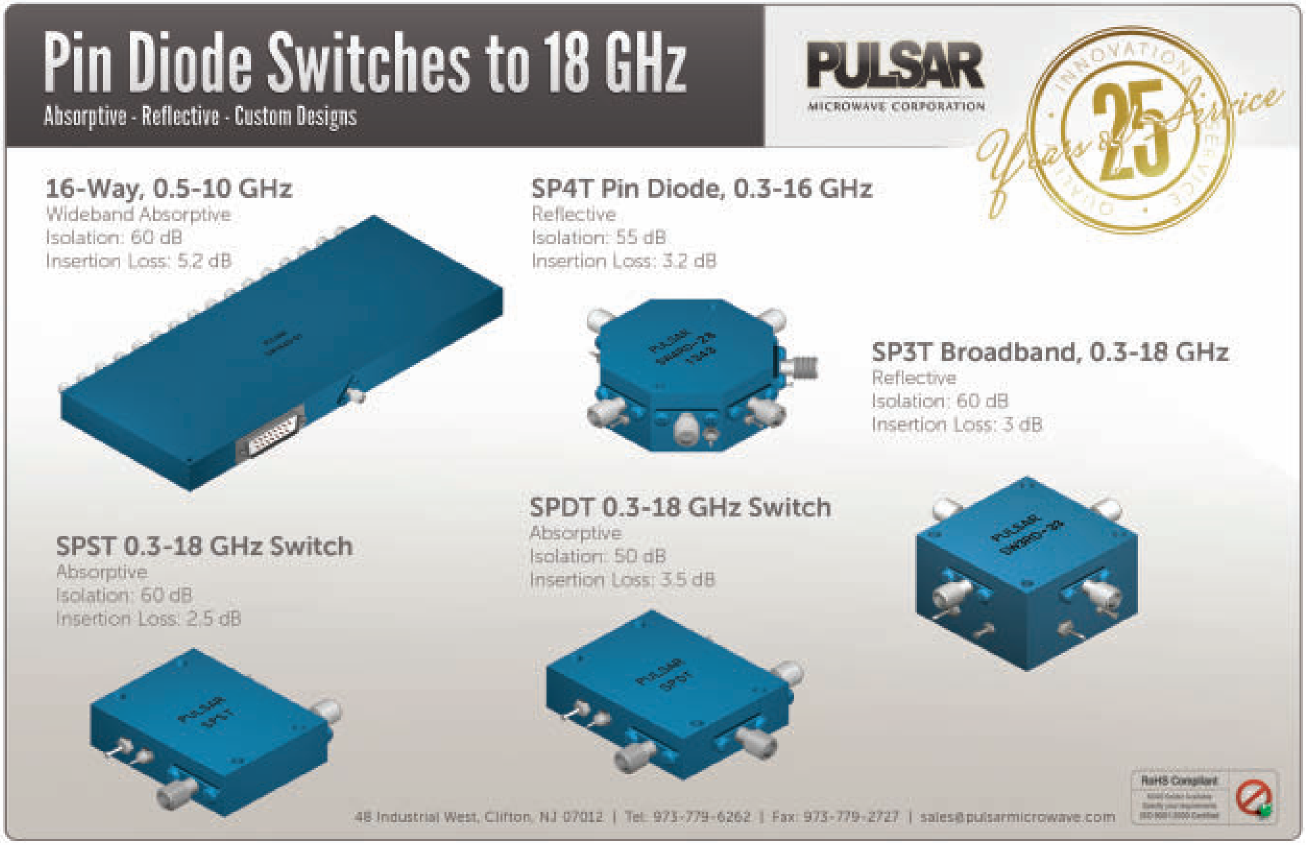


▲ *Fig. 14 Fabricated detectors; shunt (a), series (b).*

MEASURED RESULTS

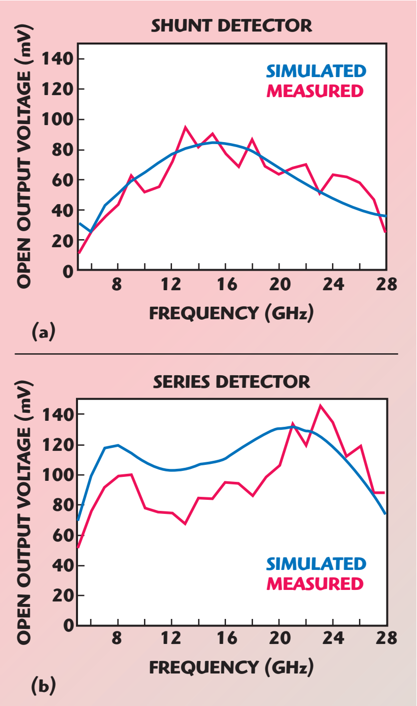
The fabricated detectors are shown in ***Figure 14***. The DC output voltages and the baseband demodulation waveforms are measured. For the DC measurements, output voltage measured with a high impedance voltmeter is proportional to the output with 50 Ω, and is more convenient to measure. Simulation with a 10 MΩ termination is compared with the measured results. The input RF power is -5 dBm. Output voltage under this condition is the open circuit output voltage. Comparisons are shown in ***Figure 15***.

Measured and simulated results agree closely in the 6 to 26 GHz band, verifying the design ideology and procedure. Small deviations are due to

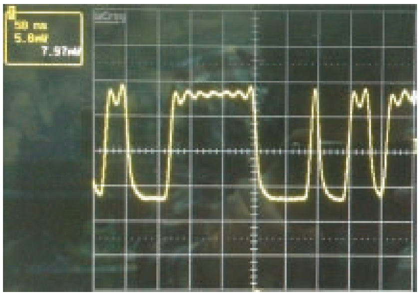


standing waves caused by mismatch, manufacturing inaccuracies or imperfections in the diode model. For the shunt detector, the open circuit output voltage varies from 25 to 82 mV, with a total fluctuation of 5.31 dB. The worst-case narrowband fluctuation is 1.59 dB. For the series detector, the open circuit output voltage varies from 68 to 146 mV, with a total fluctuation of 3.32 dB. The worst-case narrowband fluctuation is 1.07 dB. The series detector demonstrates better performance than the shunt detector. Both have total fluctuations better than 7.5 dB (reported by Alamri and Alamoudi).[6]

Figure 16 shows the demodulation waveform of a 50 Mbps ASK PRBS signal with a carrier frequency of 16 GHz, and with a 50 Ω output termination. ***Table 1*** compares the performance of these detectors with other reported results.



▲ *Fig. 15 Simulated versus measured open circuit output voltage; shunt detector (a), series detector (b).*



▲ *Fig. 16 Measured demodulation waveform (50 Mbps).*

CONCLUSION

Two types of detectors, shunt and series, are designed and fabricated. Measured output voltage responses correspond closely with the simulated results, which demonstrate the feasibility of the design procedure. The minimum open circuit output voltages of the two detectors are measured to be 25 and 68 mV, respectively, with -5 dBm input RF power. Narrowband fluctuation is less than 1.59 dB for the shunt detector and is less than 1.07 dB for the series detector. The average output voltage of the series type is higher than that of the shunt type.

Compared with other published detectors, the prototypes described in this article have very wide operating bands (6 to 26 GHz) and relatively flat frequency responses. Their imped-


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TABLE I

COMPARISON WITH OTHER PUBLISHED DETECTORS

Literature	Working Band	Application	Data Rate	Fluctuation
[2]	1 to 4 GHz	Optical Communication	648 Mbps	±1 dB
[3]	60 GHz	Near Field Communication	622 Mbps	Not mentioned
[4]	60 GHz	Near Field Communication	2 Gbps (simulated)	Not mentioned
[5]	3 to 10 GHz	UWB Communication	700 Kbps	Not mentioned
[6]	2 to 8 GHz	Mobile Communication	750 Kbps	7.5 dB
This paper	6 to 26 GHz	Optical/Mobile Communication	2.5 Gbps (simulated)	1.59 dB/1.07 dB

ance conversion networks have sufficient bandwidth to demodulate up to a 2.5 Gbps ASK signal. The detectors are suitable for use in many modern communication systems including mobile and coherent optical. ■

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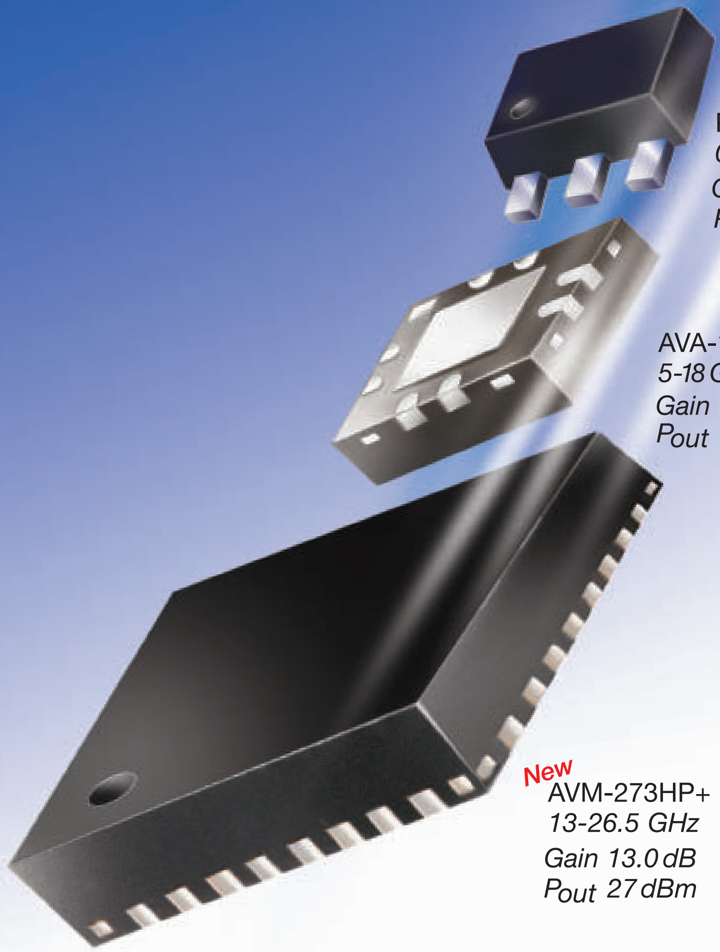

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As silicon wafers, wireless devices and military systems continue to become more complex, multiport vector network analysis with S-parameters has become an indispensable tool. For those who work on the leading edge, an important trend has emerged. A few years ago, many needed vector network analysis with four-port capability. Then, a variety of next-generation products required eight-port measurements, and some manufacturers responded. The next generation needed 16-port capability and 32-port requirements are on the near horizon.

Along with this trend, many organizations are seeking to drive down the size of test with more capability per cubic inch in their test stations. This is a subset of the larger need to drive down the cost of test to help ensure ongoing profitability as prices erode in wireless communications or as business models change in aerospace and defense.

▲ *Fig. 1 A new class of PXI VNAs offers full two-port capability—including a source—in a single slot.*

Across these industries and others, more system developers are choosing to shift a growing percentage of their capital-equipment budget to modular measurement hardware. System size will shrink whether they opt for a completely modular architecture or choose a hybrid modular/box-instrument approach. Although this will not necessarily reduce up-front costs, many expect the long-term cost of ownership to decline.

These intersecting requirements have led to the creation of a new class of vector network analyzers. Although they fit in just one slot, Keysight Technologies' new M937xA Series PXIe VNAs are full two-port vector network analyzers with frequency coverage up to 26.5 GHz (see ***Figure 1***). They perform fast, accurate measurements and reduce the cost of test by enabling simultaneous characterization of many devices—two-port or multiport—using a single PXI chassis.

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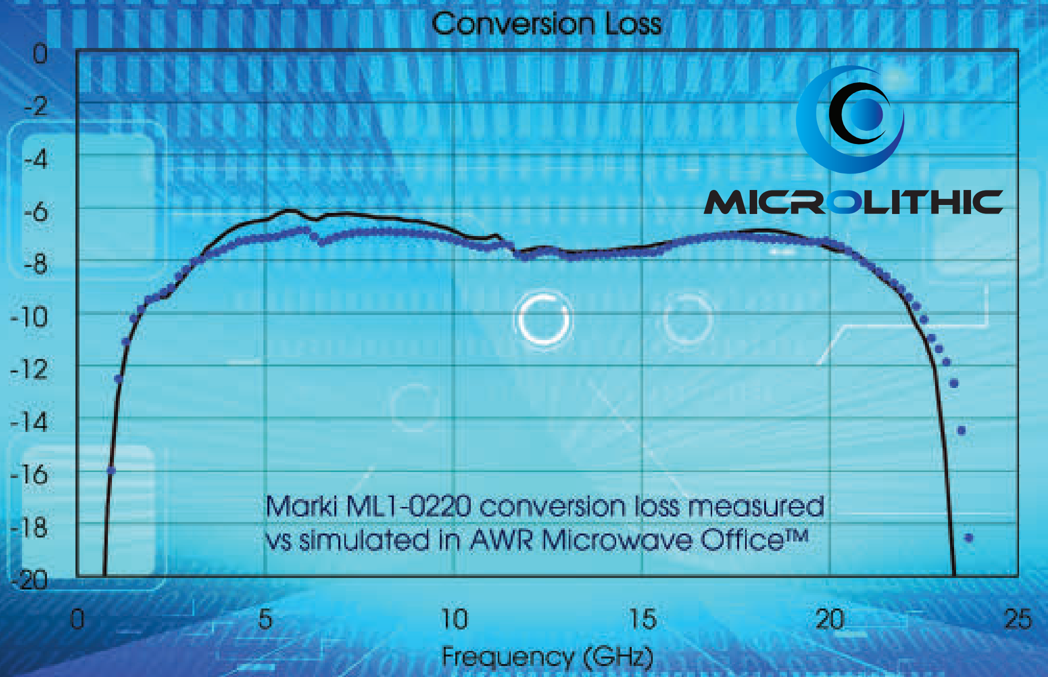

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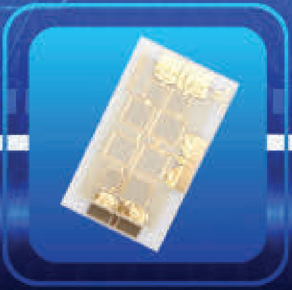

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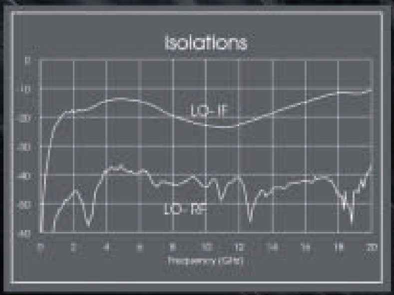

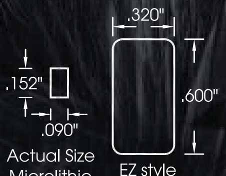

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EXPLORING EMERGING THEMES IN TESTING

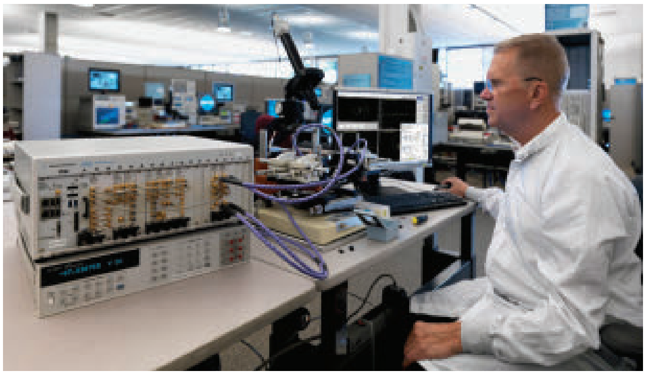

Fig. 2 Adding a pair of two-port PXI VNAs to an existing test station enables powerful device characterization without expanding system height or footprint.

Within the future needs described, three major themes have crystallized:

- The need to test highly complex devices in much less time without sacrificing accuracy
- The need to test multiple devices—and test in greater numbers—at a single test station
- The need to reduce the size of the test stations used to test multiple wafer sites or complex devices

Three types of user scenarios illustrate these needs and the desired solutions: implementing a multi-function tester, testing multiple devices or sites and testing complex multiport devices.

Many system creators have implemented multi-function testers within a single PXI chassis. As the chassis fills up, fewer slots are available to incorporate VNA capability. A one-slot PXI VNA is ideal for this situation—and that's why Keysight's engineers endeavored to create this compact solution.

On the production line or in a wafer fab, there is a growing need to test multiple devices or multiple wafer sites at a single test station. Examples include components for mobile handsets, military radios and increasingly dense silicon wafers. In such situations, one of the key needs is to reduce the overall size of the test solution. The ability to install multiple two-port PXI VNAs in a single chassis provides a tremendous space reduction when compared to using multiple benchtop analyzers on the production line or alongside a probing station (see ***Figure 2***).

As devices become increasingly complex, there is a need to easily characterize a full set of S-parameters on a large number of ports—eight, sixteen, or more. Examples include RF front end modules (FEM), multiple-input/multiple-output (MIMO) antennas, smart antennas and phased-array transceiver modules.

Specifically, total characterization of a FEM used in mobile handsets requires S-parameter measurements on ten or more ports. In addition, full N-port correction is needed to ensure accurate results.

Those developing MIMO antennas need to investigate antenna mutual coupling, which can affect system performance. They can do this through channel measurements which entails simultaneous S_{21} measurements for all combinations of transmit and receive antennas. Full N-port correction is also needed here to ensure accuracy.

Whether the focus is on multi-site testing or characterization of multiport devices, it should be easy to reconfigure a set of modules in a single chassis into arbitrary groups of N-port VNAs. For example, a single chassis containing sixteen two-port VNAs could be configured as eight four-port VNAs, four eight-port VNAs or one 32-port VNA.

COMPARING APPROACHES

In multi-site testing, today's typical solutions use either a VNA with a switch matrix or multiple stand-alone VNAs. Compared to using a switch matrix, a PXI-based approach created around one-slot PXI VNAs can enable faster throughput with the ability to make simultaneous measurements on differing numbers of ports, at different frequency ranges, or with segmented sweeps (e.g., power level, IF bandwidth, etc.) optimized for speed and accuracy. Compared to using multiple VNAs, the compact PXI VNA has a few key advantages: lower total cost; smaller footprint and shorter height; and closer placement relative to DUTs or handler stations. Additional advantages include easier scalability when

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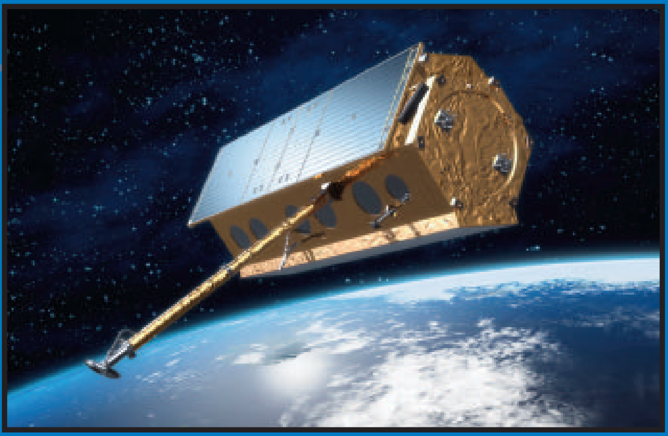

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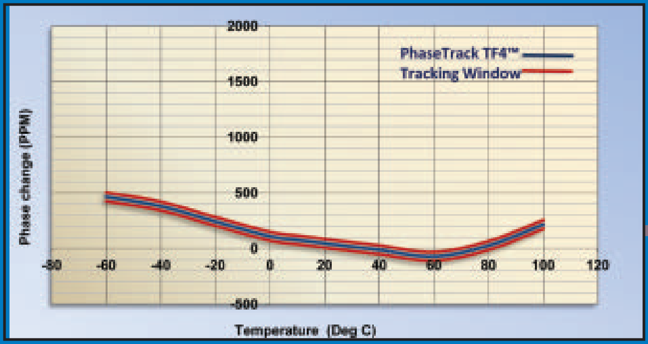

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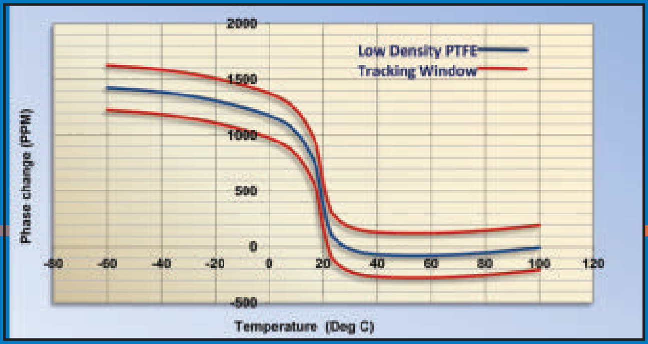

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more ports are needed and the ability to add signal analysis, signal generation, and more, in open slots.

For multiport testing, the available solutions are based on either a multiport VNA or VNA plus a switch matrix. Compared to a typical multiport VNA, the one-slot PXI VNA offers more flexibility in frequency range, and this can mean lower up-front cost and simpler upgrades when moving to higher frequencies. The PXI VNA also offers greater flexibility in port count, letting the system creator add ports in increments of two rather than four, which is common with box VNAs. This level of flexibility also translates into greater uptime: if a module fails, it can be easily removed and replaced.

Compared to a switch-matrix solution, the PXI-based approach has the same advantages in throughput and size described previously. In addition, the use of multiple two-port VNAs typically provides higher performance in terms of dynamic range and directivity by eliminating the signal degradation that can be caused by cascaded external switches.

▲ *Fig. 3 The family provides consistent speed and performance across a choice of six frequency ranges.*

COMPACT TEST SOLUTIONS

Until very recently, when limited VNA capabilities became available in the PXI form factor, the default frame of reference—for manufacturers and end users—was benchtop instruments. Over the years, Keysight has enhanced many of its benchtop VNAs with capabilities that increased the number of ports that can be measured simultaneously. The downside: solutions that require more than eight ports often become unwieldy in terms of size, cabling, complexity and power consumption.

The one-slot PXI VNA puts full two-port capabilities in a device that is just 3.75" × 7" × 0.75" (95 × 178 × 19 mm). The single-slot package contains a surprising amount of performance in terms of speed, trace noise, stability and dynamic range. The foundation of that performance is a combination of proven, high-performance components and a pair of high-density circuit boards.

Six models are available, reaching from 300 kHz to 4, 6.5, 9, 14, 20 or 26.5 GHz (see ***Figure 3***). This enables system creators to purchase the frequency coverage they need now and easily upgrade it in the future.

Of course, calibration is the other key to accurate, repeatable S-parameter characterization. The PXI VNA uses the same measurement science and the same proven, trusted calibration routines found in Keysight's PNA family of microwave network analyzers: through-reflection-line (TRL), short-open-load-through (SOLT) and specialized calibration routines. In addition, the PXI VNA offers guided calibrations, full multiport calibration

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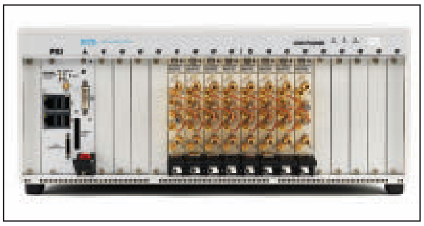
capability and is compatible with Keysight's electronic calibration (ECal) kits as well as mechanical calibration kits.

FLEXIBLE COMBINATIONS AND CONFIGURATIONS

All of these capabilities can be configured to satisfy the range of scenarios described earlier: a one-slot, two-port VNA for a compact multifunction tester, up to sixteen two-port VNAs in a single chassis, or cascaded modules that create a flexible combination of multiport VNAs in one chassis (see ***Figures 4*** and ***5***).

If necessary, multiple PXI chassis' can be connected and synchronized to enable even greater test capacity in a small footprint. For these configurations, each chassis must have its own embedded controller to manage measurement activity, data reduction and data transfers. In all cases, larger port counts will benefit from a more powerful embedded controller in the chassis.



▲ *Fig. 4 This versatile multiport configuration uses sixteen two-port PXI VNAs in a single chassis.*

▲ *Fig. 5 This multi-site configuration example includes a quartet of independent four-port PXI VNAs in a single chassis.*

Measurement functionality is scalable through a range of software options. At introduction, optional capabilities include time-domain analysis, N-port calibrated measurements and advanced fixture-simulator capabilities.

The PXI VNAs also provide a graphical user interface that shares the familiar look and feel of Keysight's benchtop PNA family. This eases the transition to PXI for benchtop users developing solutions in R&D or manufacturing.

GAINING A MEANINGFUL EDGE

Whether end users are testing active or passive devices, the right mix of speed and performance in vector network analysis provides a meaningful edge in today's highly competitive industries. Increasingly, business requirements also dictate the need for greater flexibility and a smaller physical footprint. The new class of one-slot, two-port PXI VNAs offers choices in form factor and flexibility that address present and future needs in aerospace, defense, wireless communications and semiconductors.

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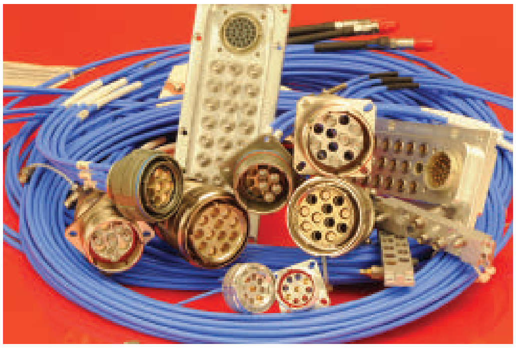


Multiport Connectors Evolve

Spectrum Elektrotechnik GmbH
Munich, Germany

In the evolution of multiport connectors, Spectrum Elektrotechnik GmbH has played an important and key role in developing products that offer practical solutions. Years ago all interconnections were made by using standard connectors, such as N, TNC, BMA, SMA, etc. However, as packaging density became a requirement, smaller connectors (such as SSMA) were developed. Although connectors became smaller, space was still needed for connecting and disconnecting, using a wrench for tightening and loosening.

The development of snap-on connectors was a breakthrough that addressed the need for connections in compact situations but one problem still existed – manually connecting every single line. The more assemblies to be connected, the greater the possibility of making a wrong connection as well as the issue of connections becoming loose during vibration or shock – although connectors like the full detent SMP already provide a safe connection.

FOOLPROOF CONNECTIONS

The use of the MIL-DTL-38999 shells and the development of size 8 and 12 connectors for microwave connections was a first step in the right direction towards making proper connections in seconds for a number of microwave lines. The availability of five different keyed shells (0 and A to D) reduced the risk of connecting the wrong shells and made connections foolproof. Patterns from several manufacturers became available, usually mixing a number of microwave inserts of size 8 or 12, with a number of signal lines included.

The system is useable for low frequency applications, but there is a disadvantage at higher frequencies. The soft rubber does not guarantee exact alignment of size 8 or 12 contacts or the perfect mating of the male/female interfaces, which is a prerequisite for high frequency applications.

Advanced installations require a high number of connections in as small a shell as possible and often require only microwave connections and not signal lines. The microwave cable assemblies must be low loss and must utilize high density dielectrics, since long cable lengths are often required. Applications for such cable assemblies are in surveillance aircraft and other vehicles that use microwave equipment. Similarly, there can be a large number of cable assemblies in medical applications and test centers, which must be connected safely and quickly.

Spectrum Elektrotechnik GmbH was the first company to develop the circular SQ-Series, using the MIL-DTL-38999 shell, series 3, size 21, packing eight microwave cable assemblies of 4.3 mm diameter as compactly as possible (see ***Figure 1***). In addition, the series features the quick replacement of defective assemblies, using bayonet catch inserts and operating to 24 GHz with low VSWR.

The TQ-Series was developed to address the requirement for more connections and low loss microwave lines to be connected within seconds. It adheres to MIL-DTL-38999 with a size 25 shell, connecting up to 12 low loss microwave cable assemblies of 3.2 or 4.3 mm diameter in seconds, using the proven front end design of the SQ-Inserts for the frequency range up to 24 GHz and newly designed inserts for applications to 40 GHz.

CABLE ISOLATION

The TQ-Series (shown in ***Figure 2***) is available for 12, 10, 8, 7 and 4 microwave cable assemblies using 7.6 mm diameter cable assemblies with a low loss of 0.65 dB/m (0.2 dB/feet) at 18 GHz. Since the TQ-Series uses a common ground among the cable assemblies within one shell, the IQ-Series has been designed to isolate the assemblies from each other.

▲ *Fig. 1 The traditional SQ-8, connecting 8 low loss cable assemblies in seconds.*

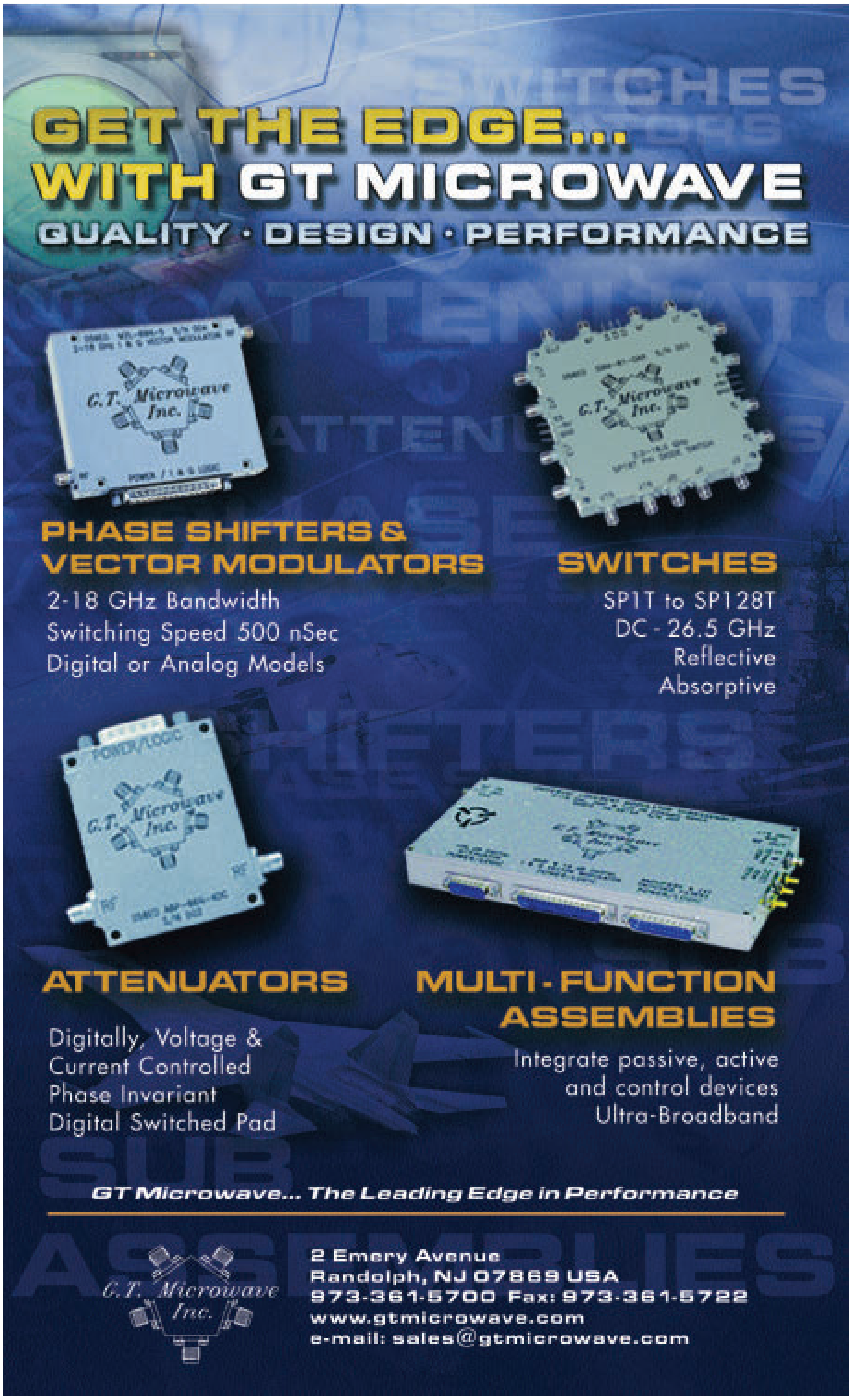
▲ *Fig. 2 The TQ-Series, connecting up to 12 assemblies in size 25 shell per MIL-DTL-38999.*

Although it takes only seconds to connect series 3 MIL-DTL-38999 shells, the shells of MIL-DLT-38999, Series I, incorporating a bayonet catch system, has been developed to provide even faster connection and disconnection. While the BQ-Series employs common ground cables, the CQ-Series isolates the cable assemblies from each other within the circular shell.

Certain applications demand specific solutions. An aircraft, for example, has one multiport outside and one mating port inside. Therefore pressurized units are offered that satisfy tests in accordance with EIA-364-02C.

Since size 21 and 25 circular shells are too big for certain requirements, Spectrum has used the MIL-DTL-38999, size 13, circular housing that packs nine 2.4 mm diameter microwave cable assemblies into the housing and operates to 40 GHz. The design goal is a VSWR of 1.2:1 max at 40 GHz with the current VSWR of 1.35:1.

Spectrum Elektrotechnik GmbH is currently engineering a size 25 circular unit, carrying 19 microwave cable assemblies and operating to 40 GHz. An additional development is a multiport design to 67 GHz (see ***Figure 3***), incorporating a minimum nine assemblies in a size 13 circular shell adhering to MIL-DTL-38999, guaranteeing a maximum VSWR of 1.35:1 for each pair of the assemblies at 67 GHz.



HIGH POWER

5 - 500 WATTS PRODUCTS

POWER DIVIDERS RoHS ✓

Model #	Frequency (MHz)	Insertion Loss (dB) [Typ./Max.] ◊	Amplitude Unbalance (dB) [Typ./Max.]	Phase Unbalance (Deg.) [Typ./Max.]	Isolation (dB) [Typ./Min.]	VSWR (Typ.)	Input Power (Watts) [Max.] •	Package
2-WAY								
CSBK260S	20 - 600	0.28 / 0.4	0.05 / 0.4	0.8 / 3.0	25 / 20	1.15:1	50	377
DSK-729S	800 - 2200	0.5 / 0.8	0.05 / 0.4	1 / 2	25 / 20	1.3:1	10	215
DSK-H3N	800 - 2400	0.5 / 0.8	0.25 / 0.5	1 / 4	23 / 18	1.5:1	30	220
P2D100800	1000 - 8000	0.6 / 1.1	0.05 / 0.2	1 / 2	28 / 22	1.2:1	2	329
DSK100800	1000 - 8000	0.6 / 1.1	0.05 / 0.2	1 / 2	28 / 22	1.2:1	20	330
DHK-H1N	1700 - 2200	0.3 / 0.4	0.1 / 0.3	1 / 3	20 / 18	1.3:1	100	220
P2D180900L	1800 - 9000	0.4 / 0.8	0.05 / 0.2	1 / 2	27 / 23	1.2:1	2	331
DSK180900	1800 - 9000	0.4 / 0.8	0.05 / 0.2	1 / 2	27 / 23	1.2:1	20	330
3-WAY								
S3D1723	1700 - 2300	0.2 / 0.35	0.3 / 0.6	2 / 3	22 / 16	1.3:1	5	316
4-WAY								
CSDK3100S	30 - 1000	0.7 / 1.1	0.05 / 0.2	0.3 / 2.0	28 / 20	1.15:1	5	169S

• With matched operating conditions

HYBRIDS RoHS ✓

Model #	Frequency (MHz)	Insertion Loss (dB) [Typ./Max.] ◊	Amplitude Unbalance (dB) [Typ./Max.]	Phase Unbalance (Deg.) [Typ./Max.]	Isolation (dB) [Typ./Min.]	VSWR (Typ.)	Input Power (Watts) [Max.]	Package
90°								
DQS-30-90	30 - 90	0.3 / 0.6	0.8 / 1.2	1 / 3	23 / 18	1.35:1	25	102SLF
DQS-3-11-10	30 - 110	0.5 / 0.8	0.6 / 0.9	1 / 3	30 / 20	1.30:1	10	102SLF
DQS-30-450	30 - 450	1.2 / 1.7	1 / 1.5	4 / 6	23 / 18	1.40:1	5	102SLF
DQS-118-174	118 - 174	0.3 / 0.6	0.4 / 1	1 / 3	23 / 18	1.35:1	25	102SLF
DQK80300	800 - 3000	0.2 / 0.4	0.5 / 0.8	2 / 5	20 / 18	1.30:1	40	113LF
MSQ80300	800 - 3000	0.2 / 0.4	0.5 / 0.8	2 / 5	20 / 18	1.30:1	40	325
DQK100800	1000 - 8000	0.8 / 1.6	1 / 1.6	1 / 4	22 / 20	1.20:1	40	326
MSQ100800	1000 - 8000	0.8 / 1.6	1 / 1.6	1 / 4	22 / 20	1.20:1	40	346
MSQ-8012	800 - 1200	0.2 / 0.3	0.2 / 0.4	2 / 3	22 / 18	1.20:1	50	226
180° (4-PORTS)								
DJS-345	30 - 450	0.75 / 1.2	0.3 / 0.8	2.5 / 4	23 / 18	1.25:1	5	301LF-1

◊ In excess of theoretical coupling loss of 3.0 dB

COUPLERS RoHS ✓

Model #	Frequency (MHz)	Coupling (dB) [Nom]	Coupling Flatness (dB)	Mainline Loss (dB) [Typ./Max.]	Directivity (dB) [Typ./Min.]	Input Power (Watts) [Max.] •	Package
KFK-10-1200	10 - 1200	40 ±1.0	±1.5	0.4 / 0.5	22 / 14	150	376
KDS-30-30	30 - 512	27.5 ±0.8	±0.75	0.2 / 0.28	23 / 15	50	255 *
KBS-10-225	225 - 400	10.5 ±1.0	±0.5	0.6 / 0.7	25 / 18	50	255 *
KDS-20-225	225 - 400	20 ±1.0	±0.5	0.2 / 0.4	25 / 18	50	255 *
KBK-10-225N	225 - 400	10.5 ±1.0	±0.5	0.6 / 0.7	25 / 18	50	110N *
KDK-20-225N	225 - 400	20 ±1.0	±0.5	0.2 / 0.4	25 / 18	50	110N *
KEK-704H	850 - 960	30 ±0.75	±0.25	0.08 / 0.2	38 / 30	500	207
SCS100800-10	1000 - 8000	10.5 ±1.5	±2.0	1.2 / 1.8	8 / 5	25	361
KBK100800-10	1000 - 8000	10.5 ±1.5	±2.0	1.2 / 1.8	8 / 5	25	322
SCS100800-16	1000 - 7800	16.8 ±1.5	±2.8	0.7 / 1.0	14 / 5	25	321
KDK100800-16	1000 - 7800	16.8 ±1.5	±2.8	0.7 / 1.0	14 / 5	25	322
SCS100800-20	1000 - 7800	20.5 ±2.0	±2.0	0.45 / 0.75	12 / 5	25	321
KDK100800-20	1000 - 7800	20.5 ±2.0	±2.0	0.45 / 0.75	14 / 5	25	322
KEK-1317	13000 - 17000	30 ±1.0	±0.5	0.4 / 0.6	30 / 15	30	387

* Add suffix - LF to the part number for RoHS compliant version.
• With matched operating conditions

Unless noted, products are RoHS compliant.

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RECTANGULAR CONNECTORS

Rectangular multiport connectors often fit the system requirements better. For a special project, the RQ23-DC26 (shown in ***Figure 4***) incorporates 23 microwave cables and 26 signal connections in a rectangular housing has become a reality. Spectrum's Push-On SMAs were used as inserts to meet the customer's specific requirement for individual testing of the cable assemblies while already aligned in the shell and using standard SMA assemblies. The push-on connectors offer a float mount capability at low cost.

Fig. 3 TQ-9 Multiport: 9 × 40 GHz coaxial cable assemblies in the MIL-DTL-38999, size 13.

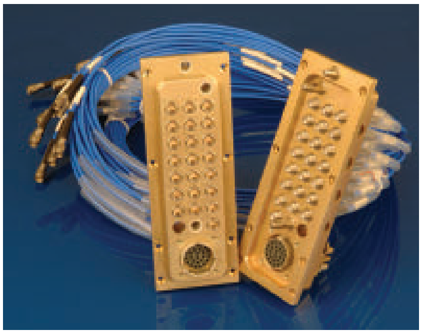

Fig. 4 The standard RQ23-DC26 using 23 coaxial microwave assemblies and 26 signal lines.

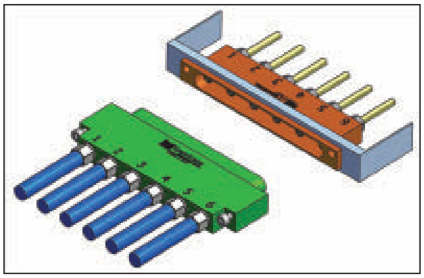

Fig. 5 The new rectangular multiport designs featuring 4, 8, 10 and 12 coax connections.

Looking forward, Spectrum Elektrotechnik GmbH is developing a number of small rectangular multiport connectors using different shapes in order to fit the system's dimensional requirements – see ***Figure 5***. The shells will carry 4, 8, 10, or 12 cable assemblies and utilize a specially developed locking mechanism.

There are proposals for carrying up to 80 connections in a rectangular multiport. Due to the high number of connections and disconnections to be made at once, focus needs to be directed to the float mount capability of the units, their safe connection and electrical performance, with special attention to the insertion and withdrawal forces and safe locking. Using its experience Spectrum Elektrotechnik GmbH is constantly developing multiport units to meet customer requirements.

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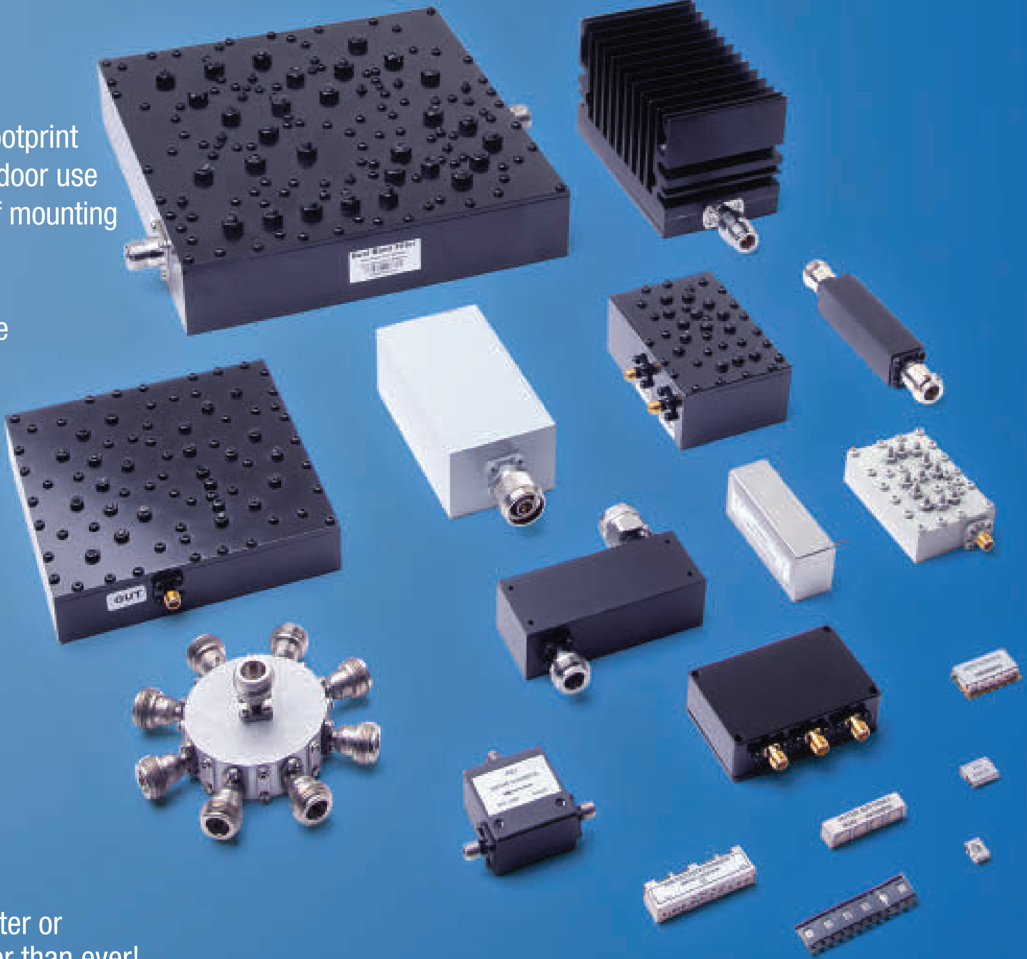

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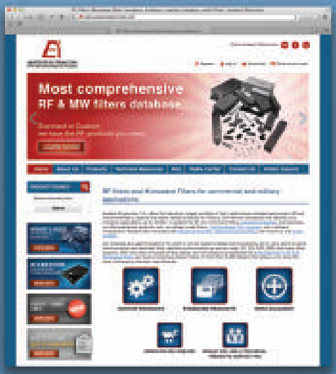

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Field-To-Lab Virtual Drive Testing Tools

Anite
Fleet, UK

Live testing of devices and network equipment in the field is a well-practiced approach to ensure interoperability and performance. It can, however, prove to be labor intensive, time-consuming and generate inconsistent results. In order to address these issues, testing has increasingly migrated to laboratory-based methods. Yet, the issue of faithfully replicating the 'field in the lab' has always proved elusive. Over recent years laboratory-based testing methods have been refined and now offer the prospect of accurate and repeatable field testing in the lab, resulting in accelerated product qualification.

Fig. 1 The Propsim F32.

Mobile operators and their supply chain use virtual drive testing to assess the performance of a device or network equipment to improve the end-user experience. Virtual drive testing is a lab-based approach that enables users to test mobile devices and infrastructure under controlled and close-to-reality radio conditions by importing field data from drive test tools and scanners. In this approach, the base station is connected to the mobile device via the channel emulator.

VDT INCREASES PRODUCTIVITY

Anite's Virtual Drive Testing (VDT) solution helps to further increase productivity as the same tool chain can be used throughout the end-to-end test and measurement cycle. Users of the Propsim-based VDT tool (see ***Figure 1***) are able to benefit from a consistent and connected approach to device automation, data logging, analysis and reporting in both field and laboratory environments. This will help users accelerate development, test planning, data analysis and reporting. With common tools for various applications, users can also reduce time spent on reporting and training staff.

The Propsim-based VDT Tool employs the field test measurements (including RF environment data) captured from real live networks by Nemo tools – Anite's branded field measurement tools that enable users to perform data

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Mechanical Characteristic	Diameter 0.195" Min. dynamic bend radius only 1"	Diameter 0.235" Min. dynamic bend radius only 1.2"	Diameter 0.3" Min. dynamic bend radius only 1.5"
Cable Insertion Loss (Typ.)	0.36 dB per Ft @ 18 GHz	0.31 dB per Ft @ 18 GHz	0.219 dB per Ft @ 18 GHz
Excellent Phase Stability vs. Flexure	± 3.6° @ 18 GHz (When wrapped 360° around a 1.95" radius mandrel)	± 3.6° @ 18 GHz (When wrapped 360° around a 2.35" radius mandrel)	± 5.4° @ 18 GHz (When wrapped 360° around a 3.0" radius mandrel)
Amplitude Stability vs. Flexure	⩽ ± 0.2 dB @ 18 GHz		
Good Phase Stability Over Temperature	250 ppm max. @ + 22 ~ + 100°C		
Operating Temperature for Cable Assembly	- 50 ~ + 125°C		
Common Features	Ultra low loss, higher power handling capacity & lighter weight compared with other similar size cables		
Application	Commercial System, Test&Measurement, Military, Aerospace,		

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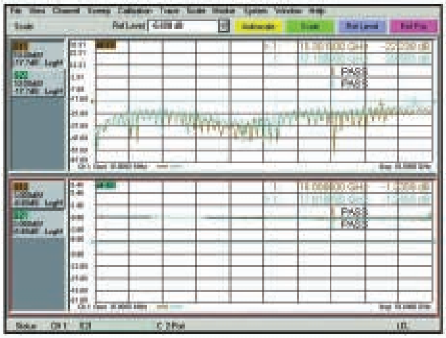
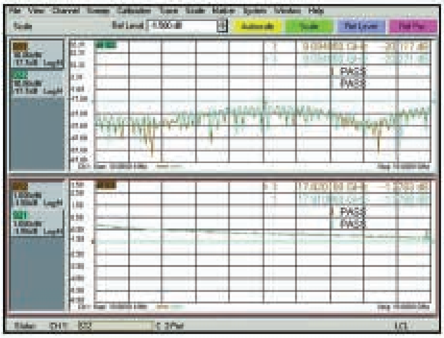
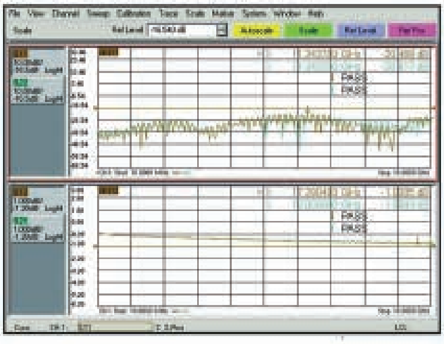
Insertion Loss and Return Loss for LL142, SMA M-SMA M, 18GHz (Typ.)



Insertion Loss and Return Loss for LL235, SMA M-SMA M, 18GHz (Typ.)



Insertion Loss and Return Loss for LL335i, SMA M-SMA M, 18GHz (Typ.)



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acquisition, analysis and reporting in the field. The user is then able to re-create repeatable, real-world RF conditions for use in laboratory-based device or network equipment testing. ***Figure 2*** shows how the VDT Tool provides RF environment playback.

VDT supports a wide range of test applications for voice and video quality, data performance and battery life testing. By replicating all elements of the real RF propagation environment (e.g. delay spread, Doppler, path loss, interference, MIMO correlation and antenna parameter effects), performance issues can be identified and resolved early in the development and design verification process.

EMULATION CAPACITY

The VDT Tool is able to benefit from the Propsim F32's RF emulation capacity that offers: 32 RF input and output channels, 128 multi-link channels and a 350 to 2700 MHz RF range. A single Propsim F32 is able to emulate RF conditions for up to 10 independent LTE MIMO mobile users in two eNodeB cells, alternatively for up to four independent LTE MIMO mobile users in four eNodeB cells. ***Figure 3*** shows the LTE Report and data analysis in the VDT Tool.

Fig. 3 LTE Report and data analysis in the VDT Tool.

Quality of service experienced by end-users on the move needs to be maintained despite varying network and environmental conditions. The fall back to legacy RATs from LTE needs to be smooth with guaranteed handover under various radio channel conditions to ensure a consistently high quality of experience. Furthermore, network elements and devices from multiple vendors need to interoperate at all times.

To this end the user of the VDT Tool is able to troubleshoot design issues under real life conditions in a repeatable and controllable laboratory environment. Once the device or network equipment has been redesigned to address the identified issues, the VDT Tool is used to verify the performance of the device using the same test conditions.

Fig. 2 VDT Tool: RF environment playback.

A CONNECTED PORTFOLIO

Through its approach Anite offers a connected portfolio with comprehensive technology and functionality support: Nemo tools offer broad device and chipset model support for device automation and data logging, while the Propsim F32 meets the design and verification challenges introduced by multifaceted wireless products that need to support multiple radio access technologies, multiple frequency bands and multiple antenna elements.

Anite
Fleet, UK
+44 1252 775200
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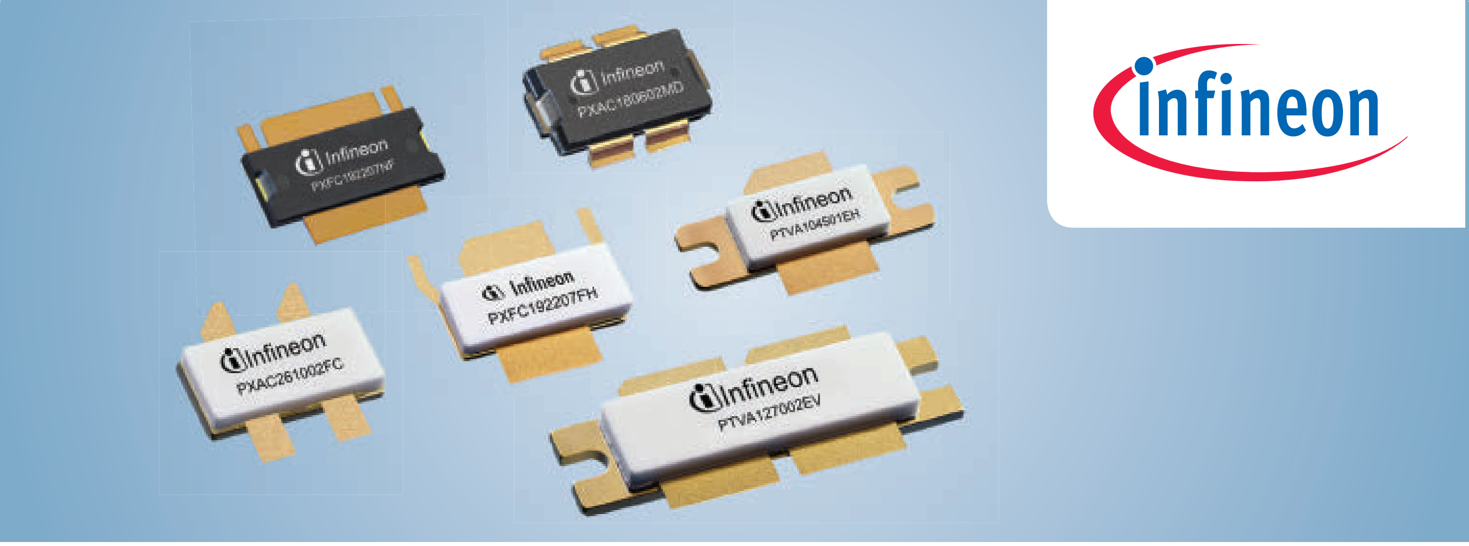

Product Information

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- 700W L-Band Transistor
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PTVA127002EV

RADAR and Avionics Product Line

Product	Operating Frequency (MHz)	Matching	@P_{1dB}			@P_{3dB}			Pulse	VSWR
			P_{OUT} (W)	Gain (dB)	Eff (%)	P_{OUT} (W)	Gain (dB)	Eff (%)		
PTVA030121EA	390 – 450	No	12	25.0	69	14	22.0	73	12µs, 10% DC	13:1
PTVA035002EV	390 – 450	No	400	19.5	65	500	17.5	67	12µs, 10% DC	13:1
PTVA104501EH	960 – 1215	I/O	450	17.0	57	490	15.0	55	128µs, 10% DC	10:1
PTVA101K02EV	1030 / 1090	I	920	18.0	56	1090	16.0	57	128µs, 10% DC	10:1
PTVA120251EA	500 – 1400	No	30	16.0	56	40	14.0	59	300µs, 10% DC	10:1
PTVA120501EA	1200 – 1400	I	54	16.5	55	63	14.5	57	300µs, 10% DC	10:1
PTVA123501EC/FC	1200 – 1400	I/O	375	16.0	56	415	14.0	57	300µs, 12% DC	10:1
PTVA127002EV	1200 – 1400	I/O	700	16.0	55	800	14.0	58	300µs, 10% DC	10:1

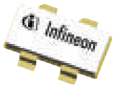
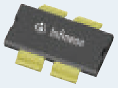
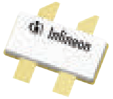
UHF/Broadcast Product Line

Product	Operating Frequency (MHz)	Matching	DVB-T Characteristics				VSWR
			P_{OUT} (W)	Gain (dB)	Eff (%)	IMD (dBc)	
PTVA042502EC/FC	470 – 806	I	55	18.5	25.5	–33	10:1
PTVA043502EC/FC	470 – 860	I	70	17.5	25.0	–30	10:1
PTVA047002EV	470 – 806	I	135	17.5	33.0	–29	10:1

www.infineon.com/rfpower

New RF Power Transistors

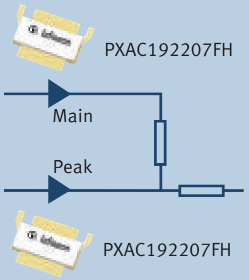
Broadband Doherty Solutions for Cellular Infrastructure

Product	Doherty-in-Package	Operating Frequency [MHz]	P_{1dB} Typ [W]	Gain Typ [dB]	Eff Typ [%]	Supply Voltage Typ [V]	Package Type
PTVA093002TC	Yes	700 – 960	2X50	19.0	50.0	50	H-49248H-4 
PXAC180602MD	Yes	1800 – 2000	21+28	18.0	50.0	28	PG-HB1DSO-4-1 
PXAC201202FC	Yes	1800 – 2200	40+80	16.0	45.0	28	H-37248-4 
PXAC201602FC	Yes	1800 – 2200	55+85	18.5	49.0	28	
PTAC240502FC	Yes	2620 – 2690	17+33	14.2	44.2	28	
PXAC261002FC	Yes	2496 – 2690	40+70	15.6	46.0	28	
NEW PXAC261212FC	Yes	2496 – 2690	50+75	15.0	48.0	28	

Cellular Doherty Reference Designs

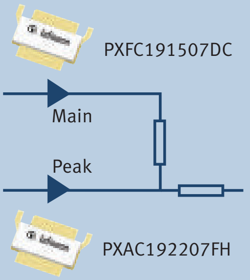
60W Symmetric Doherty
1805 – 1880MHz

P_{OUT} = 49.4dBm Avg
Gain = 16dB
Efficiency = 45%

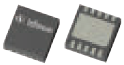


40W Asymmetric Doherty
1805 – 1880MHz

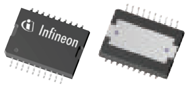
P_{OUT} = 48dBm Avg
Gain = 15dB
Efficiency = 46.5%



General Purpose Transistors (700MHz – 2200MHz)

Product	Operating Frequency [MHz]	Matching	P_{1dB} Typ [W]	Gain Typ [dB]	Eff Typ [%]	P_{OUT} Avg [W]	Test Signal	Supply Voltage Typ [V]	θJC [°C/W]	Package Type
NEW PTFC270051M	900 – 2700	Unmatched	7.3	20.3	60	–	CW @ 2170	28	3.84	PG-SON-10 
NEW PTFC270101M	900 – 2700	Unmatched	12	20.0	60	–	CW @ 2140	28	4.04	

LDMOS Integrated RF Power Amplifiers (700MHz – 2200MHz)

Product	Operating Frequency [MHz]	Matching	P_{1dB} Typ [W]	Gain Typ [dB]	Eff Typ [%]	P_{OUT} Avg [W]	Test Signal	Supply Voltage Typ [V]	θJC [°C/W]	Package Type
PTMA080152M	700 – 1000	I	20	30	34	8	GSM/EDGE	28	8.5/2.5	PG-DSO-20-63 
PTMA080302M	700 – 1000	I	32	31	36	15	GSM/EDGE	28	6.7/1.7	
PTMA180402M	1800 – 2200	I	40	30	16	5	CDMA	28	3.6/1.5	
PTMA210152M	1800 – 2200	I	20	28.5	33	7	WCDMA	28	10.7/2.9	

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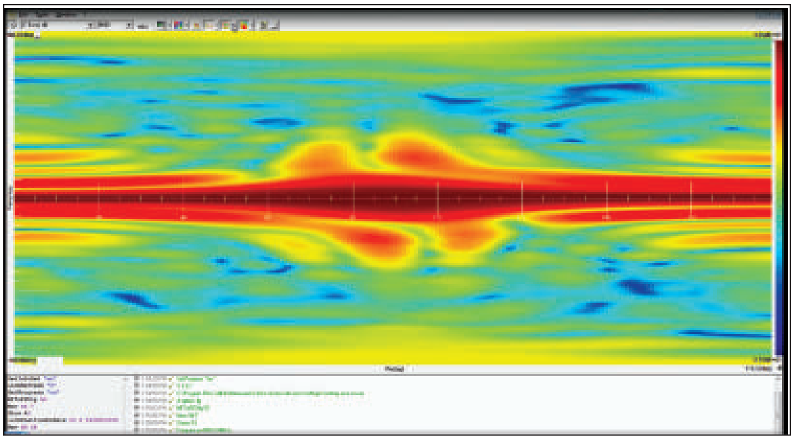
Compact and Portable Antenna Measurement Tool

Microwave Vision Group (MVG)
Kennesaw, Ga.

A large anechoic chamber traditionally represents a dedicated infrastructure, with extensive real estate and building expenses. Add to that temperature and humidity control driving up power costs and a dedicated crew operating the chamber with one or more specialists. This is why Microwave Vision Group (MVG) created StarLab as a compact and portable, all-in-one antenna measurement tool.



▲ *Fig. 1 2D far-field patch antenna measurement.*

StarLab is a multi-capability product that performs 3D passive measurements in spherical and cylindrical geometries. It can also characterize antennas in 3D OTA (spherical measurements). The system is based on patented probe array technology. The StarLab system offers the speed advantages of a probe array, while the mechanical rotations in azimuth and elevation allows for unlimited angular resolution over the full 3D sphere. By adding a linear positioner, the StarLab system can be converted to a compact cylindrical near field measurement system. This system is particularly well-suited for measurements of base stations and other sectorial type array antennas often used in


Not a problem.

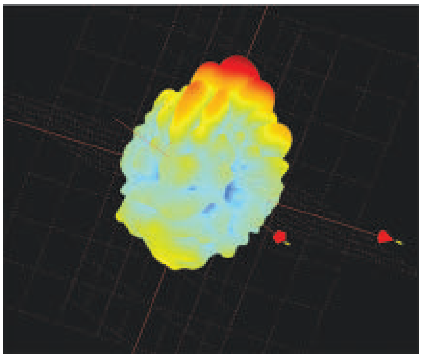
radar applications.

Because StarLab is compact and portable, it can perform measurements inside a shielded chamber, but can also perform passive measurements without the necessity of a test chamber. The StarLab doesn't require special power or temperature control.

StarLab has recently undergone a complete transformation to give it extended capabilities, as well as a new look for an improved user experience.

NEW FEATURES AND IMPROVED CAPABILITIES

- Frequency bands covered now extend as low as 650 MHz and up to 18 GHz
- Increased measurement speed up to 4 times faster than previous units
- Increased dynamic range up to 20 dB; the frequency range of StarLab now fully supports Wi-Fi, LTE and upcoming protocols, making StarLab fully prepared for the next generation of telecommunication devices



▲ *Fig. 2 3D far-field view of patch antenna with WaveStudio software.*

- Rubberized absorbers added for increased life span, ruggedness and a dust-free environment
- Fiber optic lighting added to the arch to facilitate visibility of the device under test (DUT)
- Auto calibration is significantly improved
- Upcoming software updates (starting with SAM—Satimo's specific software to drive OTA measurements) offer a much more user-friendly interface and feature new capabilities such as batch measurements and an integrated viewer.

USING STARLAB

The StarLab system is a compact, near field measurement system, with field sampling performed by a wideband probe array. The array is composed of a number of evenly spaced elements along the circumference of the support structure.

In the spherical near field configuration, the antenna under test (AUT) is positioned in the centre of the system on top of a very low dielectric column. The full-sphere measurement is performed by electronically scanning the probe array in elevation and rotating the DUT 180° in azimuth (see ***Figure 1***). This enables a full 3D measurement to be performed rapidly (see ***Figure 2***).

The probes are dual-polarized, wideband printed elements specifically designed and optimized for probe array applications. The probe array elements are mounted on a circular arch and embedded in multi-layer conformal absorbers, keeping the reflectivity of the probe array at a minimum. The internal diameter of the StarLab probe array is 90 cm, measured from

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Model	Frequency (MHz)	Gain (dB)	Pout @ Comp. 1 dB (W)	Pout @ Comp. 3 dB (W)	$ Price (Qty. 1-9)
ZVE-3W-83+	2000-8000	36	2	3	1295
ZVE-3W-183+	5900-18000	35	2	3	1295
ZHL-5W-2G+	800-2000	45	5	6	995
ZHL-5W-1	5-500	44	8	11	1020
ZHL-10W-2G	800-2000	43	10	13	1295
• ZHL-16W-43+	1800-4000	45	13	16	1595
• ZHL-20W-13+	20-1000	50	13	20	1395
• ZHL-20W-13SW+	20-1000	50	13	20	1445
LZY-22+	0.1-200	43	16	32	1495
ZHL-30W-262+	2300-2550	50	20	32	1995
ZHL-30W-252+	700-2500	50	25	40	2995
LZY-2+	500-1000	47	32	38	2195
LZY-1+	20-512	43	37	50	1995
• ZHL-50W-52+	50-500	50	40	63	1395
• ZHL-100W-52+	50-500	50	63	79	1995
• ZHL-100W-GAN+	20-500	42	79	100	2395
ZHL-100W-13+	800-1000	50	79	100	2195
NEW ZHL-100W-352+	3000-3500	50	100	100	3595
NEW ZHL-100W-43+	3500-4000	50	100	100	3595
NEW LZY-5+	0.4-5	52.5	100	100	1995

Listed performance data typical, see minicircuits.com for more details.

• *Protected under U.S. Patent 7,348,854*

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Fig. 3 Antenna measurement configuration and acquisition on MVG WaveStudio.

the tip of one probe to the tip of the probe on the opposite side. The probe array can rotate mechanically 11.5 degrees in either direction, thereby increasing the number of measurement points by an integer factor (oversampling factor). This feature enables the user to perform measurements with an unlimited number of sample points (see **Figure 3**).

In spherical near field configuration, StarLab usage is targeted at the characterization of electrically small antennas and wireless terminals for development, pre-qualification or pass/fail production purposes. By adding a linear positioner to the system, StarLab can be converted to a compact cylindrical near field measurement range, ideally suited for measuring fan-beam antennas that concentrate the radiation in primarily one plane. The number of near field samples in the azimuth plane can be adjusted by the rotation of the probe array and the sampling along the AUT can be adjusted independently according to the frequency and dimension of the AUT.

MEASUREMENT OF X-BAND RADAR

The StarLab system in cylindrical configuration validated the radiation performance of the Consilium Selesmar X-Band radar. These kinds of aerials are slotted-waveguide, flare based, aerials built to sustain the high peak power of a magnetron. The microwave radiator under test was 9 feet long (2.74 meters) and emitted fields were vertically polarized, thus the waveguide was slotted on the narrow edge.

IEC 62388, which defines marine navigation radar characteristics, requires that azimuth side lobes of antennas must be under 28 dB between ± 10° from maximum gain direction and under -30 dB elsewhere. The radar antenna was tested in the 9.3 to 9.5 GHz frequency range. The measurement of the radiation pattern confirmed the compliance of the antenna performance with the antenna specifications in terms of side lobe level at 9340 MHz.

Microwave Vision Group (MVG)
Kennesaw, Ga.
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www.microwavevision.com


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700 to 2700 MHz Rack Mount 100 W Amplifier

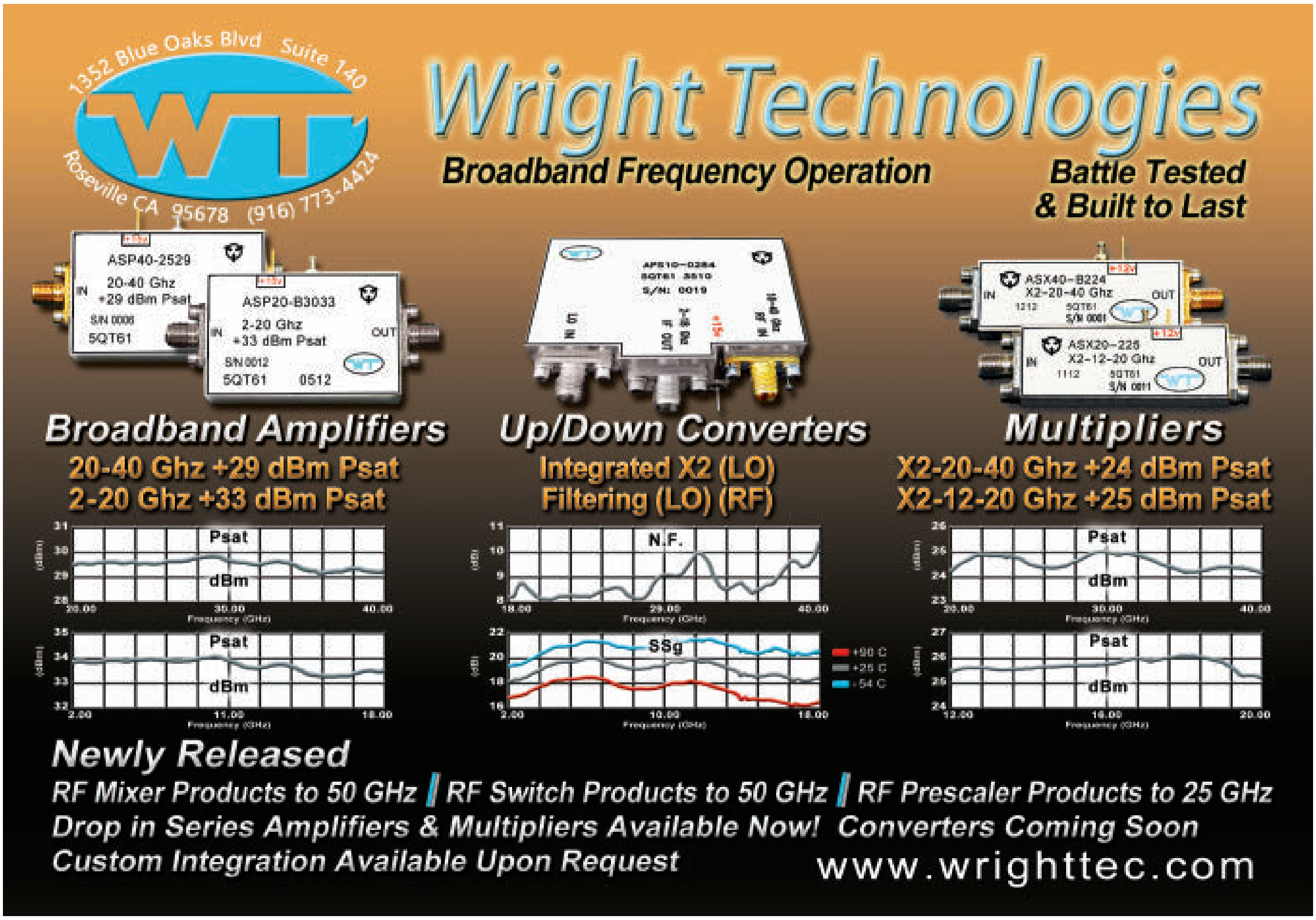
Mini-Circuits has introduced the HPA-272+ high power rack mount amplifier that is capable of amplifying signals up to 100 W across the operating bandwidth of 700 to 2700 MHz. This new model delivers 48 dB typical gain with ±1.7 dB gain flatness across its operating frequency range. Its wide bandwidth covers popular application bands including wireless communications, SATCOM and radar in a single instrument, and its high gain performance and output power support a variety of high power test applications such as EMI, reliability testing, RF power stress testing, and more.

The amplifier operates on a standard 110/220V AC line power supply, making setup quick and easy in lab environments. Extensive safety features to prevent amplifier damage include over-temperature protection with automatic shutoff above 85°C and the ability to handle short/open loads. It comes housed in a rugged, 3U rack-mountable case with N-Type RF connectors, DB-9 connection on the front panel, and internal cooling fans, which makes it ideal to use in test equipment racks.

The HPA-272+ provides high reverse isolation (89 dB typical), thereby isolating load reflections. It achieves wide dynamic range with a typical noise figure of 8.2 dB and IP3 performance of +55 dBm, and is rated for operating temperatures from 0° to 50°C. The HPA-272+ high power amplifier is offered from stock at a very competitive price of $8,995 each – approximately one-third the cost of competitive products.

VENDOR**VIEW**

Mini-Circuits
Brooklyn, N.Y.
www.minicircuits.com



High Performance RF/Microwave Cable Assemblies

Maury Microwave's Stability™ series RF and microwave cable assemblies are now available up to 50 GHz with 2.4 mm precision connectors. Stability assemblies have been specifically designed for phase-stable and amplitude-stable applications, such as measurements with VNAs, and have a typical phase stability with flexure of ±6 degrees at 50 GHz, and a typical amplitude stability with flexure of ±0.05 dB at 50 GHz. Excellent electrical properties, including a typical VSWR of 1.3:1 at 50 GHz, insertion loss of 1.52 dB/ft at 50 GHz and shielding effectiveness of over 90 dB, make Stability assemblies ideal for a wide range of daily-use applications including interconnections between instruments and test devices, bench top and wafer-level characterization, and production test. With a flex life cycle of over 20,000 and a crush resistance of over 254 lb/inch (44 kN/m), Stability assemblies offer a ruggedized and durable construction with a longer lifespan and lower cost-of-test. Stability assemblies have been designed for high-density applications, such as PXI systems and high-density switches, and have an outer diameter of 0.244 inches (6.20 mm), a static bend radius of 1 inch (25.4 mm) and nominal weight of 1.02 oz/ft (95 g/m). Stability assemblies operate between -67° and +257°F (-55° to +125°C), are fire resistant, abrasion resistant and RoHS/REACH compliant.

Stability cable assemblies are part of the ColorConnect™ family. Following the proposed IEEE high frequency connector/adapter color convention, Stability cable assemblies are the first commercially available assemblies to offer clear indications of compatibility and intermatability. ColorConnect makes it a simple matter to avoid and eliminate damaged equipment, degraded equipment reliability, degraded performance and lengthy maintenance times due to improper mating (and attempted mating) of incompatible interconnects.

Stability cable assemblies are also available up to 26.5 GHz with 3.5 mm connectors, up to 40 GHz with 2.92 mm connectors, and can be ordered in swept-90° and TVAC configurations. Standard lengths are available in-stock for next-day delivery at www.maurymw.com/store.

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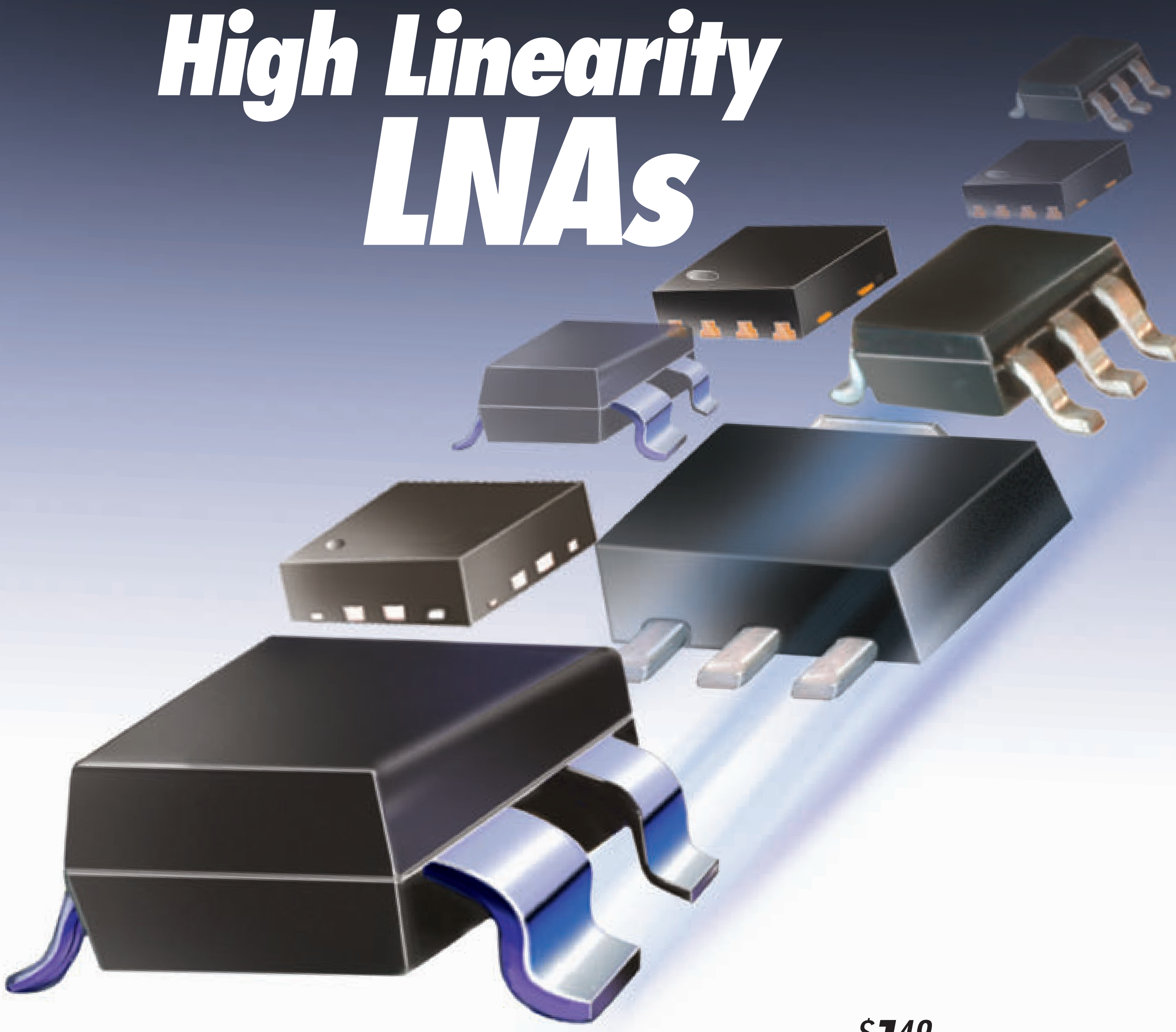
High Linearity LNAs



***NF** as low as 0.5 dB • **IP3** up to 43 dBm • **DC** current 20 mA and up* from $1.49 ea. (qty. 20)

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♻ ***RoHS compliant***

Model	Freq. (MHz)	Gain (dB)	NF (dB)	IP3 (dBm)	P_{out} (dBm)	Current (mA)	Price $ (qty. 20)
PMA2-162LN+	700-1600	22.7	**0.5**	**30**	20	55	2.87
PMA-5452+	50-6000	14.0	**0.7**	**34**	18	40	1.49
PSA4-5043+	50-4000	18.4	**0.75**	**34**	19	33 (3V) 58 (5V)	2.50
PMA-5455+	50-6000	14.0	**0.8**	**33**	19	40	1.49
PMA-5451+	50-6000	13.7	**0.8**	**31**	17	30	1.49
PMA2-252LN+	1500-2500	15-19	**0.8**	**30**	18	25-55 (3V) 37-80 (4V)	2.87
PMA-545G3+	700-1000	31.3	**0.9**	**33**	22	158	4.95
PMA-5454+	50-6000	13.5	**0.9**	**28**	15	20	1.49

Model	Freq. (MHz)	Gain (dB)	NF (dB)	IP3 (dBm)	P_{out} (dBm)	Current (mA)	Price $ (qty. 20)
PGA-103+	50-4000	11.0	**0.9**	**43**	22	60 (3V) 97 (5V)	1.99
PMA-5453+	50-6000	14.3	**0.7**	**37**	20	60	1.49
PSA-5453+	50-4000	14.7	**1.0**	**37**	19	60	1.49
PMA-5456+	50-6000	14.4	**0.8**	**36**	22	60	1.49
PMA-545+	50-6000	14.2	**0.8**	**36**	20	80	1.49
PSA-545+	50-4000	14.9	**1.0**	**36**	20	80	1.49
PMA-545G1+	400-2200	31.3	**1.0**	**34**	22	158	4.95
PMA-545G2+	1100-1600	30.4	**1.0**	**34**	22	158	4.95
PSA-5455+	50-4000	14.4	**1.0**	**32**	19	40	1.49

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High Spectral Purity Synthesizer

The HSX Series was developed to be one of the cleanest CW sources available. Phase noise performance, spurious rejection and harmonic/sub-harmonic rejection were the primary focal points during the development cycle. The result is a high performing, broadband CW source.

The HSX Series was initially released as a 10 MHz to 6 GHz CW source with subsequent models operating to 10 and 20 GHz. This series of broadband frequency sources exhibit industry leading phase noise and spectral purity performance coupled with a highly accurate dynamic range of +18 to -110 dBm. The 1U high form factor will be available in 1, 2, 3 or 4 channel models; all providing the ultimate in frequency accuracy, channel-to-channel stability and phase coherent channels. The 10 and 20 GHz models are anticipated by early 2015.

Phase noise is a critical performance parameter for high speed communications systems, subsystems, components and chipsets. The phase noise performance of the HSX Series is derived from years of development of proprietary techniques that optimize both close-in phase noise (long term stability) and far-from-the carrier phase noise (instantaneous stability), while maintaining true phase coherency.

At 6 GHz, the phase noise is -86 dBc/Hz at 10 Hz offset, -126 dBc/Hz at 10 kHz offset and -138 dBc/Hz at 10 MHz offset. Phase noise at 1 GHz is -144 dBc/Hz at 10 kHz offset. Harmonics are well below -40 dBc and all spurious artifacts are less than -87 dBc.

Holzworth RF Synthesis products come with a three-year warranty against manufacturing defects and offer industry leading spectral purity.

VENDORVIEW

Holzworth Instrumentation
Boulder, Colo.
(303) 325-3473
www.holzworth.com

Handheld Microwave Spectrum Analyzer

Spectrum Compact is a light and easy to use measurement solution for the 6 to 40 GHz licensed microwave frequency bands. Designed specifically for comfortable outdoor use in a variety of challenging environments, this battery-powered device has been developed for microwave radio engineers performing equipment installation, link troubleshooting, site maintenance or gathering data for site planning purposes.

One of the most prominent features of the SAF Spectrum Compact is its form factor. The dimensions of the device are close to those of a cell phone, making it one of the smallest and lightest spectrum analyzers currently available.

Instead of focusing on features that would only be useful in a laboratory environment, this device has the qualities and functionality frequently requested by microwave field engineers to efficiently perform their daily tasks – radio parameter verification, antenna alignment, interference and multipath detection, power in band measurements and link troubleshooting, while saving the spectrum curves for reports and further analysis.

The unit utilizes a resistive touch screen for ease of use in the field, while still allowing the engineer to wear gloves to manipulate the device. Spectrum Compact's high sensitivity (-105 dBm) and low noise floor enables field engineers to detect even exceptionally week signals. The device has the capability to perform a multitude of tasks from the ground level, and troubleshoot links without interrupting site traffic.

A standard kit includes the spectrum analyzer, an RF cable and a waveguide adapter. The waveguide adapter itself can be used as a low gain antenna. Just by pointing it towards the transmitting radio, the Spectrum Compact will detect and visualize the incoming signal. The instrument is compatible with any manufacturer's antenna and SAF also provides a set of handheld horn antennas for use with Spectrum Compact as an additional interference detection accessory in case a parabolic antenna is not available onsite.

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What'll We Think of Next?

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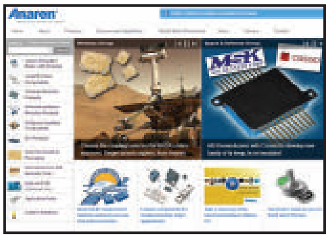

Anaren Inc. is a Syracuse-based, global leader in RF and microwave technology used in wireless infrastructure, satellite, defense and consumer-electronics applications. The company has approximately 1,000 employees and five state-of-the-art facilities worldwide. Product lines include: standard passive components (couplers, power dividers, baluns, resistors, attenuators, terminations); RF multichip modules, high-reliability softboard and ceramic PCBs and complex assemblies (switching, beamformers, antenna feed networks, DRFMs, IMAs). Visit Anaren's website for datasheets, app notes, user guides and video library.

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A New Look

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AR has made numerous changes to enhance both their corporate and RF/Microwave Instrumentation websites by giving them a more modern look and feel, offering easier navigation and providing more comprehensive information. The menu system and flash spotlights have been redesigned to work with various touch screen tablets and mobile devices. Enhanced streamlining of code makes the menus much more search engine friendly and easier to read. Check out the corporate website at www.arworld.us or the AR RF/Microwave Instrumentation website at: www.arww-rfmicro.com.

AR RF/Microwave Instrumentation
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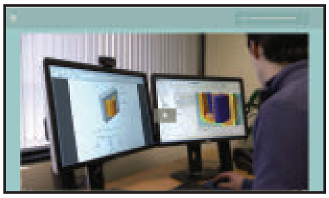
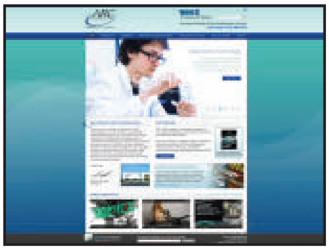
Electrical Showcase



The electrical showcase recently added to COMSOL's website features technical content about how electrical systems, devices and components can be effectively modeled using COMSOL Multiphysics® and its add-on products. Through a series of how-to videos, user case studies, white papers and example models, the showcase explores how a design idea can most accurately be represented and tested using Multiphysics simulation. Read first-hand accounts from world-renowned companies detailing how Multiphysics modeling has helped improve electrical device design, shortened time to market and allowed innovative concepts to be quickly explored. Visit www.comsol.com/showcase/electrical.

COMSOL Inc.
www.comsol.com

Website Revamp



ARC Technologies' website revamp greatly improves key features of their web presence. ARC offers a complete range of standard and custom absorbers, from 50 MHz to 110 GHz for diverse RF and EMI problems. The company's refined product finder will make all available product information and data sheets more accessible. New products and services offered will be highlighted, including new R&D testing capabilities, plus daily updates and discussions about ARC news.

ARC Technologies Inc.
www.arc-tech.com

Epoxy Pastes and Films

The Bonding Source website is the RF/microwave engineer's go-to site for quick and easy access to information on various epoxy pastes and films. The site has brief application descriptions, information on cure and storage times, and quick links to the datasheets for all epoxies. Comprehensive information on epoxy film pre-forms, bonding wire and ribbon and bonding tools is also included. All products are in stock, and ready to ship with no minimum charges.

Bonding Source
www.bondingsource.com

New Product Release Feature

Comtech PST, an industry leader in wideband solid state high power amplifiers solutions, has added a new 'product release' feature to their home page. Visitors to the site can quickly learn of Comtech's latest new product release and request more information. There is also a link to all previous product releases via the news page drop-down menu. A Comtech e-blast will be announced shortly. Send a request to e-blast@comtechpst.com to be added to the company's mailing list.

Comtech PST Corp.
www.comtechpst.com

A Complete Makeover

Living in the information age, it is more important than ever for a business to have a well-designed website. That is why CTS' website is getting a complete makeover. Their new site will have an appealing unique design while keeping it simple, clean and user-friendly. The site will be offered in English, simplified Chinese, Japanese and German. It will also be tablet and mobile friendly. CTS' new website is coming soon - make sure you go and check it out!

CTS Corp.

www.ctscorp.com

Temperature Control Systems

A redesigned website with temperature test and conditioning content for design and manufacturing engineers has been introduced by inTEST Thermal Solutions. The new site delivers information about temperature controlled environments including thermal chambers, temperature plates and mobile air forcing systems for both commercial and MIL-STD applications. Users are presented with configurations, applications and the company's resource center to download information. The website is also responsive to mobile devices, enabling easy viewing information on any device.

inTEST Thermal Solutions (iTS)

intestthermal.com

Comprehensive Display

MITEQ Inc. has developed a website that features one of the most comprehensive displays of standard and custom capabilities in the industry. The site now includes a web store where customers can order components from stock via a major credit card. It also includes a company profile, listing of career opportunities, representatives and custom engineering contacts. Customers can also check out product specifications, outline drawings, test data, manufacturing flow diagrams and an assortment of technical application notes.

MITEQ Inc.

www.miteq.com

WebUpdate

A New Web Experience

VENDORVIEW

The new ni.com has gone live in 50 countries. Users will immediately notice the website's redesigned look and feel, but the real scope of these changes goes far beyond a cosmetic facelift. NI has incorporated client feedback about navigability and organization to provide a more intuitive, user-friendly experience. They have also moved some content around, renamed a few categories and added quick access pull-down menus from the main global navigation bar. Take some time to look around the new ni.com and familiarize yourself with the updated features.

National Instruments Corp.
www.ni.com

New Product Offerings

Pivotone Communication Technologies has updated its website to include some newly developed product offerings. One product is their indoor broadband quadruplexer which combines 700, 850, PCS and AWS. Designed for high power DAS or POI systems, LTE can be added to existing sites while providing a low insertion loss and a high degree of isolation (minimum 50 dB) between systems. PIM is guaranteed to be lower than -153 dBc. Check it out at www.pivotone.com/_d276783884.htm.

Pivotone Communication Technologies Inc.
www.pivotone.com

Simple Cable Assembly Builder

VENDORVIEW

San-tron's new website features a robust product finder, which pulls from San-tron's extensive library of RF and microwave coaxial connectors and adapters, as well as a simple, user-friendly cable assembly builder. Both tools feed into their new 'my quote' system, which allows multiple products to be added at once. Using San-tron's cable builder subsystem, engineers can select their desired flexible, hand formable or semi-rigid cable type, add the RF coaxial connectors of their choice and specify unique performance needs such as low loss, low PIM, pressurized or other high performance traits.

San-tron Inc.
www.santron.com

Streamlined Navigation

VENDORVIEW

Pickering Interfaces' newly redesigned website, www.pickeringtest.com, offers detailed information on their vast array of PXI, LXI, PCI and GPIB switching and instrumentation products for use in electronic test. The new site is equipped with streamlined navigation, allowing users to quickly reference product information and easily download product datasheets, manuals and other product literature. Also new to the site is a 'request a quote' function and the ability for users to register to receive product updates and news.

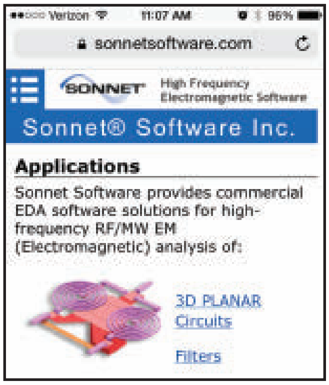
Pickering Interfaces Ltd.
www.pickeringtest.com

Expanded Features

RLC Electronics Inc. has expanded the 'new products' feature on their website, adding press releases, photos, electrical information and outline drawings where available. Some of the company's latest releases include Ka-Band cavity filters, high frequency notch filters, miniature SP2T switches with MS connectors, phase trimmers and integrated assemblies such as switched filters. RLC will continue to publish new products in this section moving forward on a monthly basis.

RLC Electronics Inc.
www.rlcelectronics.com

Optimized for Mobile Devices



Sonnet® Software Inc.

Applications

Sonnet Software provides commercial EDA software solutions for high-frequency RF/MW EM (Electromagnetic) analysis of:

3D PLANAR
Circuits
Filters

Looking for 3D Planar EM information on the go? Sonnet Software's website is now optimized for mobile viewing. Do your research or watch training videos from your smart phone or tablet device with the intuitive new web design. Browse the product pages to find out more information on the Sonnet Suites and Sonnet's new Blink package, learn how to download Sonnet Lite for your PC, or check out the company's training class schedule with ease, all from your mobile devices.

Sonnet Software Inc.
www.sonnetsoftware.com

Attention SATCOM Users

Tango Wave, a global provider of SATCOM power amplifier products, manufacturers high-power, high-linearity ODU TWTAs and subsystems designed for DTH, DSNG/SNG, broadcasting, voice/data, mobile up-linking and maritime applications. Tango Wave's new website is designed for ease of use in learning about the company's wide range of products and services for commercial, military and government users of SATCOM. Amplifier products cover Ku, DBS and Ka-Band frequencies with power levels up to 1250 W; including options for redundancy, power combining and block up-converters.

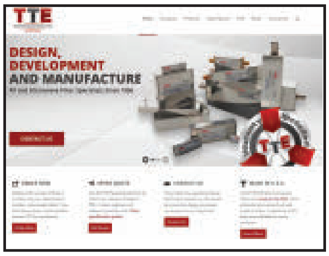
Tango Wave
www.tango-wave.com

Enhanced Search Tools

Check in often at TMS for current in-depth details about the company's advanced microwave innovations for demanding aerospace, military, commercial and industrial applications. TMS has streamlined their website navigation, expanded product and services information, and added new features such as enhanced search tools to make your user experience easy and efficient.

Teledyne Microwave Solutions (TMS)
www.teledynemicrowave.com

RF and Microwave Filters



TTE Filters designs and manufactures custom passive filters with frequencies from 0.1 Hz to 40 GHz. All products are made in the U.S. and most are delivered within two weeks. Expedited lead times of 3 to 5 days available on certain products. TTE's recently revamped website offers quick navigation to filter designs, data, graphs, case selection guides and other helpful information. Their designs include bandpass, band rejection, lowpass, highpass and high power lowpass. Information on diplexers/multiplexers is also provided. A new capabilities section addresses custom design options in terms of frequencies and topologies which include Bessel, Butterworth, Chebyshev, Elliptical Function and Gaussian. Try their new online speed quote.

TTE Filters
www.tte.com

WebUpdate

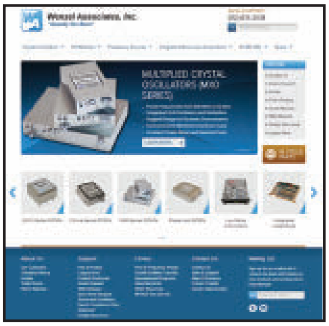
Oscillators & Timing Solutions

VENDORVIEW

Vectron International is a designer and manufacturer of precision oscillators and timing solutions for communication, industrial, military and space applications. Vectron combines its expertise in bulk acoustic wave (BAW), surface acoustic wave (SAW), mixed signal technology, packaging, sensors and product integration to field best in-class solutions that help customers achieve differentiation in the markets they serve. Headquartered in Hudson, N.H., Vectron has operating facilities and sales offices in North America, Europe and Asia.

Vectron International
www.vectron.com

Crystal Oscillator Products



Visit Wenzel's new website and learn why world-class performance and innovative design characterize them as the leader in low phase noise crystal oscillators, synthesizers and frequency related modules. Their new site was designed with a fresh, new look, user-friendly navigation and has been updated with the latest information on all things Wenzel. Since 1978, the company has defined state-of-the-art in ultra-low phase noise while providing system manufacturers with the highest quality, cost effective frequency components and instruments.

Wenzel Associates Inc.
www.wenzel.com

High Power RF Components

Werlatone.com now offers a fully interactive website that features a detailed product search function and NEW landing pages highlighting their custom designs and high power absorptive filters. Customers now have the ability to send in their specs for customization of RF directional couplers, RF combiner/divider and absorptive filters. The company's new products page also highlights several new designs that are decades ahead of the competition. A complete collection of product datasheets and audiovisual presentations are also available.

Wertalone Inc.
www.wertalone.com

EuMW 2014 Exhibitor List

The following list is complete as of August 20, 2014. Exhibitors in red have an ad in this issue.

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Keysight Technologies Booth 100

Waveform Generator

M8195A arbitrary waveform generator provides highest combination of speed, bandwidth and channel density. Keysight's M8195A arbitrary waveform generator (AWG) provides up to 65 GSa/s, 20 GHz bandwidth and up to 4 channels in a one-slot AXIe module—simultaneously. As devices and interfaces become faster and more complex, the M8195A AWG gives you the versatility to create the signals you need for digital applications, optical and electrical communication, advanced research, wideband radar and satellite communications. Go where you have never been able to test before: in speed, in bandwidth and in channel density—explore your possibilities.

www.keysight.com/find/M8195A

Signal Analyzer

The Keysight M9290A CXA-m PXIe signal analyzer is the industry's first signal analyzer to provide swept and FFT capabilities in the PXI form factor. It delivers fully-specified performance up to 26.5 GHz and provides best-in-class specifications in key areas. It lets you handle RF and microwave signals in four slots, and you can leverage your existing code. By utilizing the same measurement science and calibration used in Keysight X-Series signal analyzers, the CXA-m eliminates the tradeoffs between footprint and precision in signal analysis.

www.keysight.com/find/cxa-m

Vector Network Analyzers

Keysight Technologies' new, full two-port 26.5 GHz vector network analyzers fit in just one PXI slot. The Keysight M9370A series of one-slot PXI vector network analyzers (300 kHz up to 26.5 GHz) offers the best PXI VNA performance on key specifications such as speed, trace noise, stability and dynamic range. This enables the PXI VNAs to perform fast, accurate measurements and reduce the cost-of-test by enabling simultaneous characterization of many devices – two-port or multi-port – using a single PXI chassis.

VENDORVIEW

www.keysight.com/find/pxivna

Maury Microwave Booth 101A

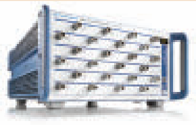
Measurement and Modeling Device Characterization Solutions

Exceptional companies have superior labs - complete your lab with Maury Microwave. Maury, a leader in measurement and modeling device characterization solutions, VNA calibration accessories and interconnections, will be showcasing active and hybrid-active harmonic load pull solutions, LXI™-certified mechanical impedance tuners, pulsed IV/RF compact transistor modeling as well as coaxial and waveguide VNA calibration kits and metrology adapters, in-stock color-coded precision and daily-use adapters, and test-port, phase-stable and value cable assemblies. Visit us for details, demos, deals and NPIs.

www.maurymw.com

Rohde & Schwarz Booth 102

R&S ZNBT VNA



Rohde & Schwarz has added the R&S ZNBT to its multi-port network analysis solutions. Depending on application requirements, the analyzer can be equipped with up to 24 test ports, thus being capable of determining all 576 S-parameters of a 24-port DUT at 201 frequency points in less than 260 ms. Covering the frequency range from 9 kHz to 8.5 GHz, the instrument offers the high RF performance of a two-port network analyzer at each of its test ports.

www.rohde-schwarz.com/product/znbt

Compact System for Fast RF Component Tests

Rohde & Schwarz has developed two new instruments: the R&S SGT100A is the smallest and fastest vector signal generator up to 6 GHz; the compact R&S FPS signal and spectrum analyzer, available for frequency ranges up to 4, 7, 13, 30 and 40 GHz, offers measurement applications for all key mobile and wireless standards. Together they can be used as a mini system for T&M applications requiring fast interaction between a signal generator and signal analyzer.

VENDORVIEW

www.rohde-schwarz.com/ad/production-tests

National Instruments/ AWR Booth 103B

V11.01 Update

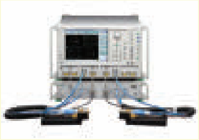
NI AWR Design Environment™ V11 introduced within its Analyst 3D FEM EM simulator new antenna measurement capabilities and a ready-built 3D parts library, as well as user-configurable 3D PCells for custom parts creation. Additionally, the V11.01 update of the NI AWR Design Environment reduced Analyst simulation times by as much as 70 percent over the previous version.

VENDORVIEW

www.awrcorp.com

Anritsu Booth 107

Broadband VNA System



The VectorStar ME7838D broadband VNA system introduces a new standard in broadband performance for customers needing to characterize on-wafer active and passive devices beyond 110 GHz. The new ME7838D broadband system extends the frequency range of the ME7838 Series to provide a single sweep from 70 kHz to 145 GHz through a coaxial test port. The VectorStar ME7838D system provides first-to-market innovation with the ability to analyze the broadband characteristics of W-Band devices beyond 110 GHz.

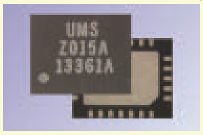
VENDORVIEW

www.anritsu.com

United Monolithic Semiconductors (UMS) Booth 108B

GaN 15 W L-Band Transistor

The CHZ015A-QEG is a GaN 15 W L-Band (1.2 to 1.4 GHz) input matched packaged transistor. It is an internally-matched Quasi-MMIC device supplied in a low cost SMD plastic package. The circuit operates in pulsed mode and features an output power of 18 W with more than 13 dB associated gain and a high PAE, up to 55%. It allows broadband solutions for a variety of RF power applications in L-Band. The CHZ015A-QEG is manufactured on a 0.5 μm gate length GaN HEMT process.



www.ums-gaas.com

CST Booth 109

CST STUDIO SUITE 2015

CST will be giving the first preview of CST STUDIO SUITE 2015, the newest version of its flagship product at EuMW, booth 109. CST STUDIO SUITE is a package of high-performance software for the simulation of electromagnetic fields in all frequency bands, and includes tools for the design, simulation and optimization of a wide range of devices. CST also has a full booth presentation program, with demonstrations to show how CST STUDIO SUITE can be applied to numerous high-frequency EM applications.

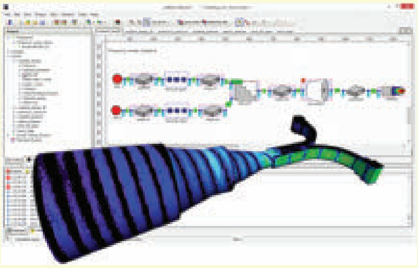
VENDORVIEW

www.CST.com


5 W TYPE-N
20 W TYPE-N
2W SMA

Mician GmbH Booth 118

µWave Wizard



Mician's µWave Wizard is an EM software tool for the design and optimization of waveguide components, horn antennas, parabol, hyperbol and ellipsoid antennas, and feed networks. The software combines the flexibility of 2D/3D FEM with the speed and accuracy of traditional Mode Matching techniques. In addition to its fast and powerful numerical methods, µWave Wizard offers an appealing and ergonomic GUI that enables flexibility and openness including CAD export formats interfacing with most mechanical design tools.

www.mician.com

Krytar Booth 119

Directional Coupler

The new directional coupler operates from 12.4 to 18 GHz and offers solutions for EW, commercial wireless, SATCOM, radar, signal monitoring and measurement, antenna beam forming and EMC testing. Model 181230 offers superior performance and delivers 30 dB (±1.0 dB) of nominal coupling and frequency sensitivity of ±0.7 dB. Directivity is >15 dB with insertion loss of <0.6 dB across the full frequency range including coupled power. Maximum VSWR is 1.35, input power rating is 20 W average and 3 KW peak.

www.krytar.com

Marki Microwave Inc. Booth 119

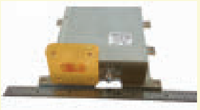
High Linearity T3 Mixers

The ultra-high linearity, broadband T3 mixers are now offered with complete frequency overlap on all three ports up to 18 GHz. The T3H-18 and T3H-20 feature RF/LO coverage of .01 to 18/20 GHz, with matching IF coverage of .01 to 18 GHz. These triple balanced mixers allow virtually any frequency plan from VHF-Ku in a single unit. With excellent spurious and two tone suppression plus low conversion loss, these arbitrary frequency conversions can be completed cleanly with wide dynamic range.

www.markimicrowave.com

Norden Millimeter Booth 119

Down Converter



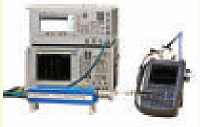
Norden's 10.7 to 12.75 GHz down converter has an IF Band 1 frequency of 950 to 1950 MHz and IF Band 2 frequency of 950 to 2000 MHz. The LO Band 1 frequency is 975 MHz and LO Band 2 frequency is 1075 MHz with an external reference frequency of 10 MHz. It has a noise figure of 0.9 dB maximum and P1dB compression point of 13 dBm. Gain is 60 to 70 dB with a flatness of ±2 dB over the full bandwidth.

www.nordengroup.com

OML Inc. Booth 119

IMD Measurements

OML introduced the industry's first direct connect solution for mm-wave Intermodulation Distortion (IMD) measurements. Fitted to characterize mm-wave devices for S-parameters and gain compression, IMD is an industry standard technique revealing the linearity of an amplifier using a two-tone measurement. Compatible with modern network analyzers such as Keysight, Anritsu and R&S, OML offers mechanical compatibility with existing probe stations, including the flexibility to upgrade existing VNA modules with IMD capabilities.



www.omlinc.com

Dow-Key Microwave Booth 122

High Power & Lightweight T-Switch

Dow-Key Microwave presents it high power T-switch 511H-series, which has been qualified and supplied to various domestic and international space programs, for both military and commercial use. Today's design is offered with 1.5 kW peak power at UHF-Band, 300 W peak power both at L-Band and S-Band, and 200 W peak power at C-Band. In addition to its superior RF performance and lightweight design, the 511H-series minimizes the switching time by using random access drive and it is available in various mounting configurations.

VENDORVIEW

www.dowkey.com

AR RF/Microwave Instrumentation Booth 126

50 W, 1 to 6 GHz Amplifier

Model 50S1G6AB is a solid-state; 50 W Class AB amplifier design that instantaneously covers 1 to 6 GHz in one unit. When used with a sweep generator, the 50S1G6AB will provide 50 W typical of RF power in approximately half the size of a traditional Class A design at a more economical price.

VENDORVIEW

www.arworld.us/html/18200.asp?id=1232

Rogers Corp. Booth 128

Thermally & Electrically Conductive Adhesive (TECA) Films

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www.rogerscorp.com

MACOM Booth 131

2-stage GaN Plastic Power Module

MACOM's MAMG-000912-090PSM is a 2-stage GaN plastic power module optimized for pulsed radar applications. This module is fully matched and can deliver pulse power levels greater than 90 W. The device operates between 960 and 1215 MHz with 60% power-added efficiency in a 14 × 24 mm surface mount laminate package. This GaN module supports surface mount technology (SMT) assembly, providing the customer significant assembly and ease-of-use advantages compared to ceramic packaged flange-mount components.

VENDORVIEW

www.macom.com

Freescale Booth 139

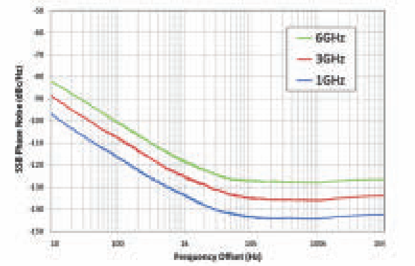
4 W RF Power Device

The AFT05MS004N is a 4 W RF power device for handheld and mobile radio applications. Freescale's Airfast RF power solutions portfolio now supports mobile radio power levels from 4 to 75 W. Features include high gain to reduce the number of stages, energy efficiency improvements that reduce heat sink form factors and exceptional ruggedness (> 65:1 VSWR) for continuous reliable operation in extreme environments. Characterized at frequencies from 136 to 941 MHz, it can operate as low as 2 MHz and is housed in the cost-effective SOT-89.

www.freescale.com

Holzworth Instrumentation Booth 146

HSX Series



Holzworth's new HSX Series broadband frequency sources exhibit industry leading phase noise and spectral purity performance coupled with a highly accurate dynamic range of +18 dBm to -110 dBm. 1, 2, 3 or 4 channel models are available in a 1U form factor; each providing the ultimate in frequency accuracy, channel-to-channel stability and phase coherency. The 10 MHz to 6 GHz product is available in 2014, with 10 and 20 GHz models being made available by early 2015. Experience a demo at EuMW booth 146.

VENDORVIEW

www.holzworth.com

Teledyne Relays Booth 148

Coax Switches

Teledyne Coax Switches has products for test and measurement, medical, industrial, defense (military) and space (HI-REL) applications. Teledyne products range from SPDT, transfer and multi-throw coaxial switches as high as SP10T. The switches are available to cover most of the RF spectrum from DC to 40 GHz and are available with SMA, mini-SMB, TNC, N or 7/16 connectors. In addition, Teledyne offers low passive intermodulation switches to achieve IP3 levels up to -165 dBc (select models) to switch microwave signals.

www.teledyne-europe.com

Teledyne Microwave Solutions Booth 148

ITAR-Free Products

TMS offers a complete suite of ITAR-Free products for Ka-Band systems specifically developed for legacy and new designs. Both up and down converters can electronically switch between commercial and military Ka/K-Bands. By combining these converters with its standard SSPA, a full transceiver can be configured operating over the 29 to 31 GHz transmit band and the 19.2 to 21.2 GHz receive band with 3 hermetically sealed modules.

www.teledynemicrowave.com

Rosenberger Hochfrequenztechnik GmbH & Co. KG Booth 149

Calibration Kit

The new 75 V calibration kit from Rosenberger is designed for applications up to 12 GHz. This high performance calibration kit contains RPC-N open, short and broadband loads and enables measurements in N 75 V applications. Additionally, measurements in BNC 75 V applications can also be realized when special adaptors RPC-N 75 V to BNC 75 V (which are included) are used. For information in detail, a new product flyer is available cost-free.

www.rosenberger.com

HUBER+SUHNER AG Booth 157

Low Loss RF Cable

The new HUBER+SUHNER low loss microwave cable assembly offers superior electrical and mechanical performance for dynamic applications. This high-end product, with an overall diameter of 5 mm, provides optimal performance up to 29 GHz and has excellent phase stability versus temperature (600 ppm) and versus bending. The PTFE wrapped cable of the Astro Boa Flex line with a typical loss of 1.27 dB/m at 26 GHz is designed for space, defence and test & measurement applications.

VENDORVIEW

www.hubersuhner.com

INGUN Pruefmittelbau GmbH Booth 157

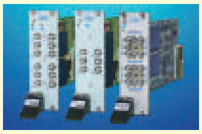
HFS-823

A new development by INGUN with a flange and advanced spring-loaded outer plunger is available for contacting switch connectors on routine tests. The inner conductor remains within the outer plunger during the complete testing phase and is therefore protected against side loading. Movements of the connection and the wire during work stroke are also avoided.

www.ingun.com

Pickering Interfaces Booth 162

PXI Microwave Switch Modules



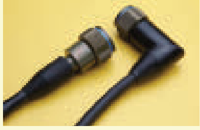
Pickering Interfaces expands its range of PXI microwave switch modules. Terminated SPDT switches have 18 GHz frequency range and offer one or two relays and option of internal or external terminations. SPDT relay modules support from one to four SPDT relays, available in a variety of different frequency options; 12.4 to 65 GHz, and a 75 Ω, 2.4 GHz version. Microwave transfer switches support either one or two transfer switches with frequency options of 18, 26.5 and 40 GHz. All modules now include LED indication of a closed signal path.

VENDORVIEW

www.pickeringtest.com

API Technologies Corp. Booth 177

Backshell Cable Assemblies



API Technologies Corp. now offers durable, low pressure overmolded backshells on connector interfaces from its Electromagnetic Integrated Solutions (EIS) product line. This simplified backshell design is readily available and more cost-effective than its metal counterpart. Ideal for use in military, aerospace, high-end industrial, oil and gas, as well as medical applications, these durable, waterproof and weather resistant backshells offer improved reliability and a simplified specification process.

www.eis.apitech.com

Pasternack Enterprises Booth 180

Broadband Amplifiers

Pasternack introduces new 1 and 2 W broadband, high gain amplifiers, ideal for defense, EW/ECM, radar, SATCOM, and microwave radio applications from 2 to 18 GHz. These broadband, high gain amplifiers have outstanding gain performance rang-

ing from 32 to 48 dB along with high linearity levels (IP3) of 39 to 42 dBm. The connectorized SMA amplifier modules are unconditionally stable and housed in hermetically-sealed casings. Each amplifier in this series is EAR99 (no export license required) and in-stock.

VENDORVIEW

www.pasternack.com

Coilcraft Booth 183

Ceramic Chip Inductors

At 0201 in size, the 0201DS series is one of the smallest wirewound chip inductors. It is offered in 52 inductance values from 0.5 to 14 nH and in high Q values up to 64 at 1.7 GHz. The 0201DS offers exceptionally high self-resonant frequencies greater than 24 GHz. It is also RoHS compliant and halogen free.

www.coilcraft.com

BeRex Booth 219

MESFET Chips

The BeRex BCF-series of MESFET chips provides a lower phase noise and higher OIP3 linearity in applications from DC to 26.5 GHz, than can be easily achieved with other technologies. These chips have a 0.3 µm gate length and are available with gate widths from 200 to 2400 µm (up to 1 W for the largest 2400 µm device). The BCF-series chips are produced in the U.S. using state of the art metallization and passivation for the highest possible reliability.

www.berex.com

TTE Filters/Gowanda Booth 219

RF & Microwave Filters

TTE Filters designs and manufactures high reliability RF and microwave filters for frequencies from 0.1 Hz to 26 GHz. Custom designs are typically available within 2 weeks of order; lead-times of 3 to 5 days are available on some products. Styles: bandpass, bandreject, lowpass, highpass, high power lowpass and cavity designs; also diplexers and multiplexers. Design capabilities: LC, combline and microstrip; topologies include Bessel, Butterworth, Chebyshev, Elliptical and Gaussian. TTE is now an affiliate of Gowanda Holdings, LLC.

www.tte.com

LPKF Laser & Electronics Booth 220

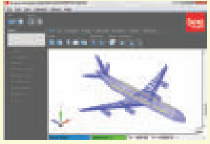
PCB Prototyping System

The LPKF ProtoMat D104 is a rapid PCB prototyping system that features both mechanical tools and a UV laser beam. By combining mechanical and laser processing, a wide range of applications are possible. The laser can be used to etch fine line circuit traces on high frequency materials and ceramics, while milling and drilling tools can be used to route boards and drill vias and through-holes.

www.lpkfusa.com

IMST GmbH Booth 222

3D EM Solver EMPIRE XPU 7.0



EMPIRE XPU is a 3D EM solver for modeling antennas, microwave circuits, EM chip design and more. Due to its unique on-the-fly compilation EMPIRE is highly efficient and extremely fast on plain conventional hardware using optimized algorithms. New features of EMPIRE XPU include a powerful and highly intuitive 3D graphical user Interface, a complete new 3D modeling kernel enabling fast import, modeling and meshing of large and complex objects, a near field source and a circuit simulator.

www.imst.com

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ZX75BP-1100+ is a wideband bandpass filter in a rugged connectorized package covering 1000 to 1200 MHz. This is designed for asymmetric rejection applications such as super-heterodyne receivers. By having asymmetric band, faster roll-off at upper side band is achieved in a comparatively smaller package and lower pass band insertion loss. It has repeatable performance across lots and consistent performance across temperature.

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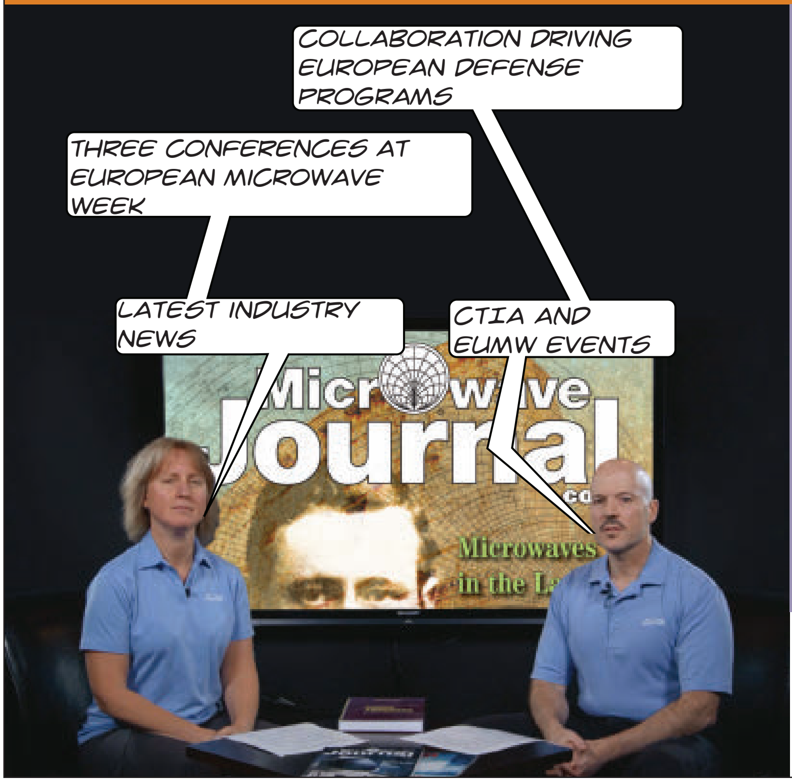

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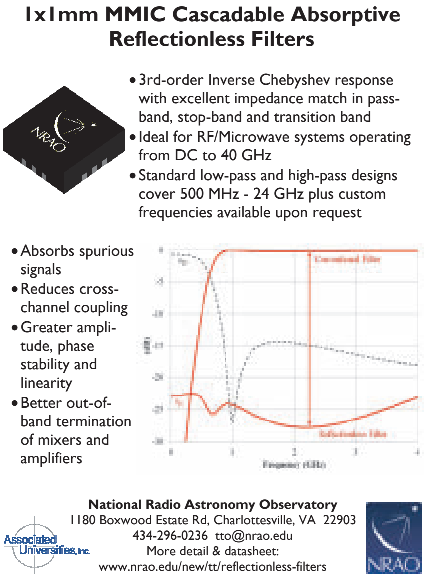

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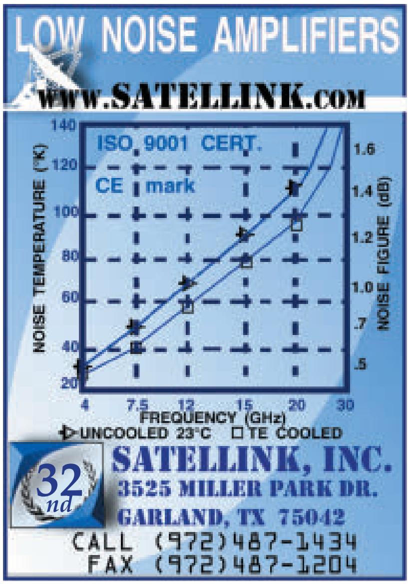

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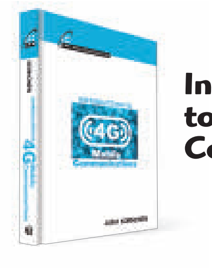

Introduction to 4G Mobile Communications

Juha Korhonen

Long Term Evolution (LTE) was originally an internal 3GPP name for a program to enhance the capabilities of 3G radio access networks. The nickname has now evolved to become synonymous with 4G. This book is about LTE-Advanced (LTE-A) that fulfills the requirements set by the International Telecommunications Union (ITU).

The book provides a history of these systems starting with first generation systems, along with an overview of a mobile telecommunications system. The overview addresses the components in the system as well as their function. This resource guides telecommunications engineers though many important aspects of 4G including the air interface physical layer, Radio Access Networks and 3GPP standardization.

Introduction to 4G Mobile Communications also covers the features of LTE-A such as energy saving, MIMO, relays, carrier aggregation, enhanced intercell interference coordination, evolved multimedia broadcast multicast service, self-organizing networks, coordinated multipoint transmission/reception and voice over LTE. It ends with consideration toward future developments for 5G with coverage of the METIS Project.

This book is a good instructional piece for both students and engineers. It provides an introduction to the world of LTE-A. It explains the LTE basics simply, oftentimes with a few examples pointing out how various issues are interconnected.

To order this book, contact:

Artech House
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Technical Paper Submissions: Authors are invited to submit technical papers describing original work on radio-frequency, microwave, millimeter-wave, and terahertz (THz) theory and techniques. The deadline for submission is 8 December 2014. Please refer to the IMS2015 website (www.ims2015.org) for detailed instructions concerning paper submission, as well as a complete list of technical areas.

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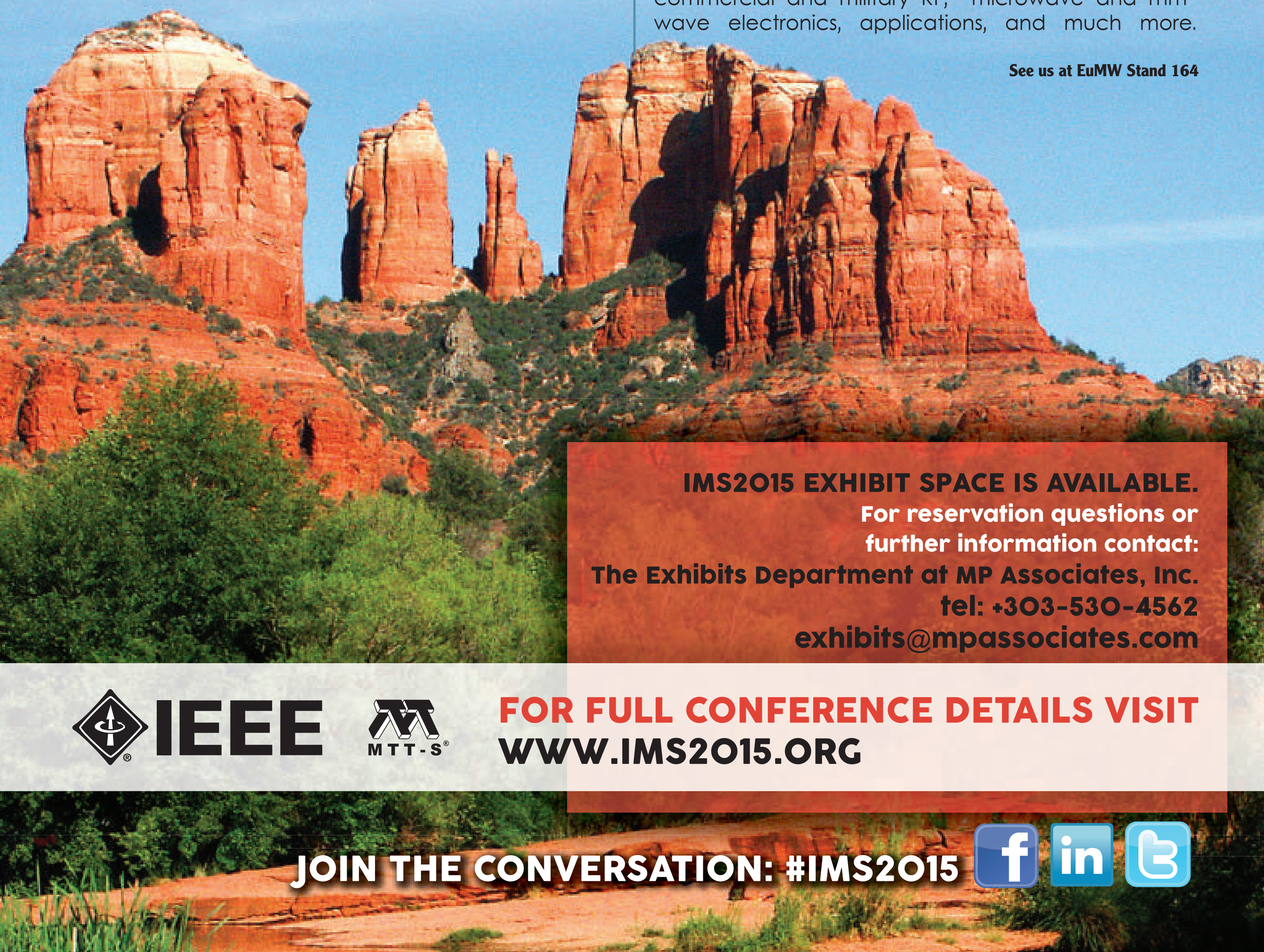

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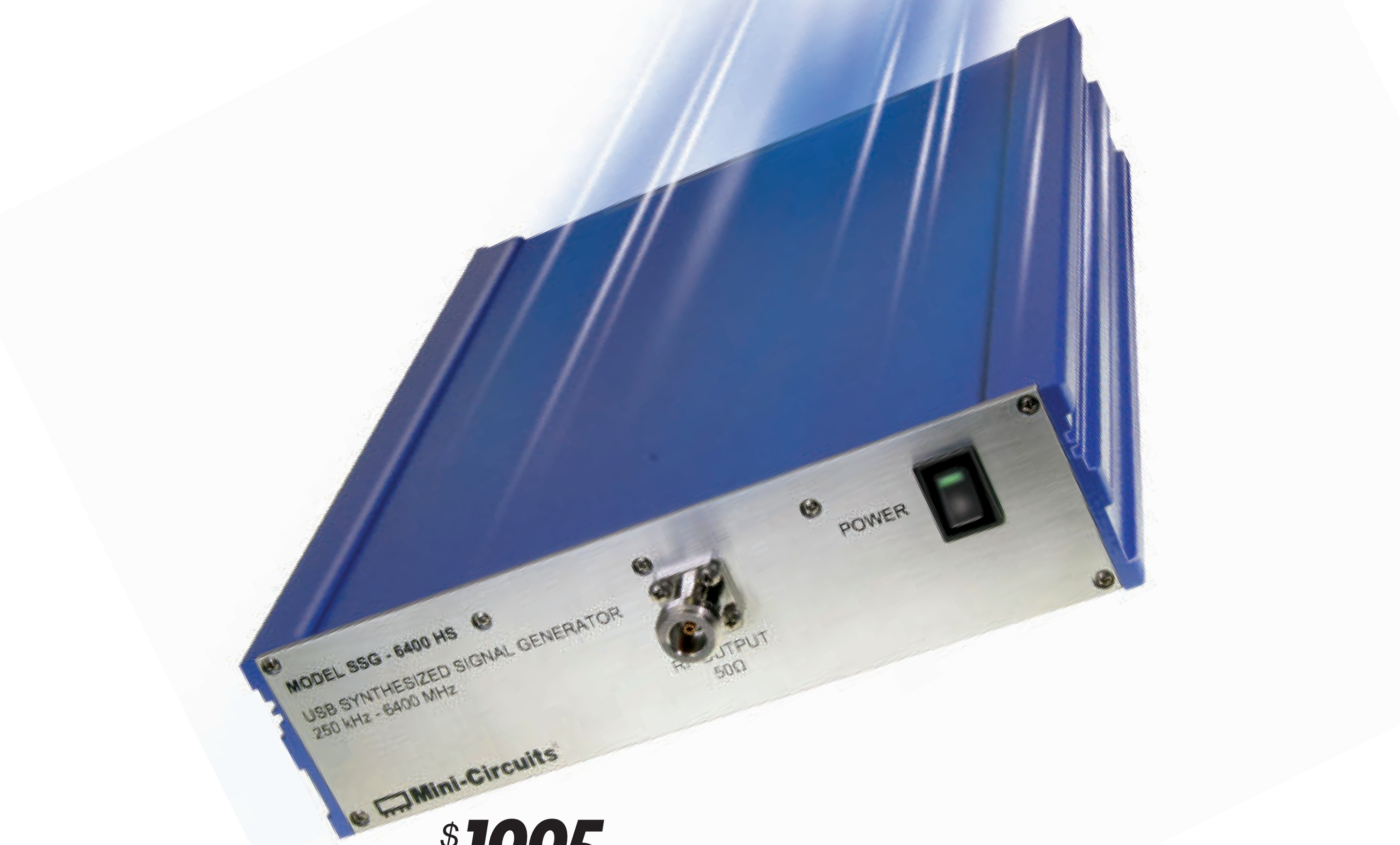

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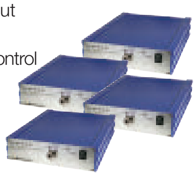

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STEM Works

Invenzione [inven-tsjone]

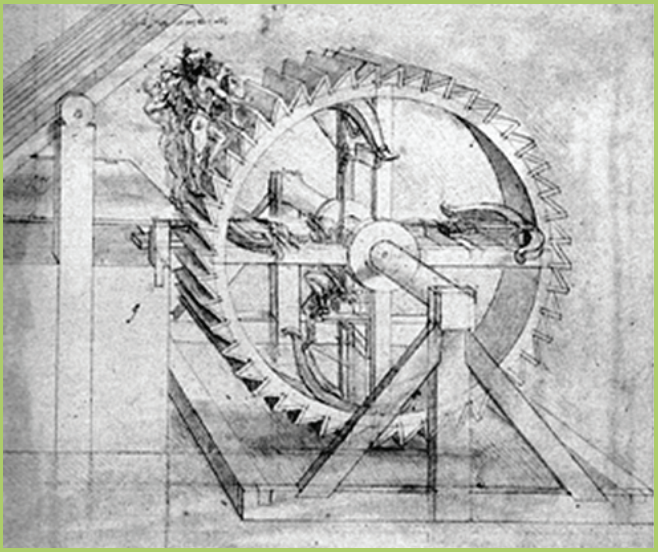
An Invenzione (invention) is a single device or a novel method, process or composition. It is a process within an overall engineering and product development process. It may be an improvement on a machine or product, or a new process for creating an object or a result.

1597 Galileo introduced a geometric and military compass, which helped users perform arithmetic and geometric calculations, including taking square and cube roots.

1800 Alessandro Volta reported the first electric battery, originally called an "artificial electric organ", based on a stack of alternating zinc and silver disks separated by brine soaked cloth.

1805 Luigi Brugnatelli invents electroplating, a manufacturing technique used to create certain metal layers in MMICs/RFICs.

1844 Innocenzo Manzetti conceives the idea of a telephone. Considered by many as the inventor of the telephone, he is believed to have made one in 1864, as an enhancement to an automaton he built in 1849.



1871 Antonio Meucci files patent caveat No. 3335 in the U.S. Patent Office titled "Sound Telegraph", describing communication of voice between two people by wire.

1895 Guglielmo Marconi proved the feasibility of radio communication sending and receiving the very first radio signal.

1903 Luigi Bezzera invented the espresso machine to speed up the coffee making process and keep hard working engineers fueled up on caffeine for all night work sessions.

1954 Propylene was first polymerized to a crystalline isotactic polymer by Giulio Natta. This pioneering discovery led to large-scale commercial production of isotactic polypropylene by the Italian firm Montecatini from 1957 onwards.

1969 Federico Faggin produced the world's first commercial integrated circuit using Silicon Gate Technology with self aligned MOS transistors while working at Fairchild Semiconductor.

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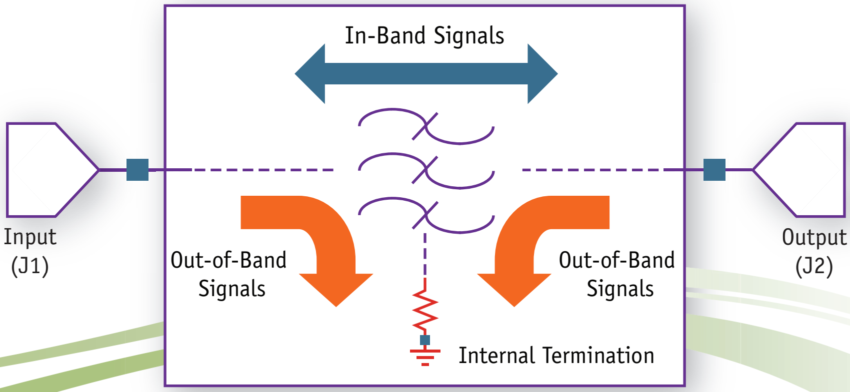

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- Excessive In-Band ripples due to out-of-band reflected energies.
- False trigger of power detector circuitry due to reflected harmonics.
- Potential damage to power amplifiers due to reflection of high power out-of-band energies.

Model	Frequency (MHz)			Power (W CW)		Insertion Loss(dB)	Rejection(dB)	VSWR	
	Pass Band	3dB Corner	Stop Band	Pass Band	Stop Band	Pass Band	Stop Band	Pass Band	Stop Band
AF9673	1-2.7	3.5	3.9-32	1,200	150	0.4	50	1.40:1	1.40:1
AF9438	1-30	32	50-380	5,000	250	0.5	50	1.30:1	1.60:1
AF9349	10-150	200	270-1500	500	25	0.4	50	1.35:1	1.60:1
AF9255	10-170	220	300-1500	50	10	0.6	50	1.25:1	1.60:1
AF9187	10-490	620	850-3000	100	10	0.5	45	1.40:1	1.90:1
AF9350	10-500	540	750-3000	400	25	0.5	45	1.25:1	1.60:1
AF9960	10-500	540	750-3000	600	25	0.5	45	1.25:1	1.60:1
AF9680	10-520	540	1040-3000	160	10	0.6	60	1.25:1	1.60:1
AF9313	10-870	1340	1700-4000	100	10	0.6	53	1.30:1	1.60:1

* Specifications are for reference only and subject to change without notice.

Werlatone, Inc. 17 Jon Barrett Road Patterson, NY 12563 (845) 278-2220 www.werlatone.com sales@werlatone.com

MACOM™

Partners from RF to Light

GaN Manifesto

MACOM™
Partners from RF to Light

John Croteau
President and CEO

The Path to Mainstream GaN Commercialization in RF and Microwave Applications

The RF and microwave industry is on the cusp of a major technology transition. This tectonic shift will be felt far and wide, impacting our industry and others in profound ways for decades to come.

The benefits of Gallium Nitride (GaN) as a wideband gap semiconductor in RF and microwave applications are becoming widely understood, and mainstream commercial applications are becoming increasingly apparent.

Reaching mass-market adoption, however, will require a much more mature supply chain and ecosystem than the one that exists today for GaN. To fully appreciate the path that we're on – and to understand what needs to happen to bring GaN into the mainstream – consider the parallels to the path Gallium Arsenide (GaAs) traveled two decades ago.

Twenty years ago GaAs was in a formative stage that's similar to where GaN is now. It was an emerging technology, the economics of which were skewed toward government funding and applications that could afford performance at any cost. As much as 50% of GaN revenues today are attributable to government programs, not commercial production. ***Just as GaAs went from esoteric technology to high-volume market mainstay, GaN is now poised to do the same.***

For GaAs, the catalyst for mainstream adoption was the explosion in consumer demand for handsets, which drove strong economies of scale. Compound semiconductor companies like ANADIGICS, RFMD and Skyworks led the industry toward the establishment of robust, reliable and scalable GaAs supply chains. They invested hundreds of millions of dollars in large-scale GaAs fabs, and made the technology transition from boutique to commercial mainstay.

In parallel, smaller GaAs fabs evolved with a capital structure and operations model to support low volume, high diversity businesses and niche process variants for performance optimization. Without exposure to consumer technology transitions and capacity underutilization, these "capital-lite" fabs are right-sized for programs that need supply continuity over decades of production.

The Revolution has Begun

The consolidation that we've begun seeing in the compound semiconductor industry is a direct consequence of GaAs being replaced in handsets by silicon-based technologies such as CMOS and SOI. The transition began with up-down converters, progressed to switches and now threatens high-power GaAs amplifiers. Silicon industry powerhouses like Qualcomm and Broadcom have announced initiatives to supplant the majority of GaAs production leveraging economies of scale that dwarf even the largest GaAs factory.

The same will hold true for high performance applications that find value in GaN. The advent of GaN on Silicon (Si) substrates promises to deliver the industry's highest compound semiconductor performance, with a cost structure that leverages economies of scale much like those displacing GaAs in handsets.

At maturity, we believe that GaN on Si will benefit from silicon cost structures that are 3X lower than today's highest volume GaAs and 100X lower cost than today's GaN on SiC technology.

Into the Mainstream

GaN is today poised to make the transition from an esoteric, government-funded technology to a high-volume commercial mainstay.

Two things are needed to facilitate such a transition. First, the technical merits of GaN technology must be fully realized and clearly demonstrated on silicon substrates. Second, a scalable, stable supply chain must be established, tapping into large commercial markets that can drive economies of scale.

1) Regarding the maturation of GaN technology, ***GaN on Si has demonstrated minimally 8X the raw power density of incumbent GaAs technology while boosting efficiency from mid-40s to as much as 70%. GaN on Si performance has now matched that of much more expensive GaN on SiC substrates.***

2) Establishing a reliable and stable supply chain entails two key steps in the manufacturing chain. The first lies in establishing a cost-effective and scalable supply of GaN materials; namely, epitaxial wafers (epi). The second involves processing those wafers through high-volume silicon fabs.

In both cases, the economics of GaN on Si technology will be driven by power conversion applications, which command unit volumes that are orders of magnitude greater than RF and microwave demand. ***Put in perspective, a full year's production for the entire RF and microwave industry can be serviced in a few weeks by a single 8" silicon factory that's built to service the power conversion market.***

MACOM recently announced an agreement with IQE, the world's premier supplier of GaAs epi, who will scale high-volume, cost-effective supply of GaN materials for cost sensitive, high-volume applications. IQE has the operational experience, competence and capital structure to scale production of GaN materials.

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As we saw with GaAs, we expect a bifurcation in the GaN supply chain for low volume applications. Cost-sensitive applications will go the path of 8" GaN on Si. At the same time, capital-lite fabs will service diverse, low-volume applications with specialty GaN processes. It's fair to expect a plethora of technology variants for niche applications, including GaN on SiC.

GaN on SiC will remain the purview of low-volume, niche applications due to the inherent cost structure of substrate material. ***Fundamentally, at a physics level, SiC boules grow 200X to 300X slower than silicon. The cost of producing substrates – notably capital depreciation and energy consumption during material growth – scales proportionally to production time. Thus, GaN on SiC will remain perpetually higher cost and thus prohibitive for mainstream commercial use.***

GaN on SiC production for the highest power density and defense applications will play to the strength of capital-lite fabs that aren't exposed to the technology transition in handsets. Such factories can support a high diversity of relatively low-volume programs, and their capital structure can ensure long-term supply without facing consolidation as handset production transitions to silicon.

Breaking the Barriers

One of the last remaining barriers to GaN adoption will be removed as the cost structure of GaN intersects and drops below that of GaAs. Once cost parity is achieved, better performing technologies always displace incumbents in the highest performance applications.

MACOM has assumed a leadership role in driving the commercialization of GaN into mainstream applications. MACOM offers the RF and microwave industry's only portfolio of both GaN on Si and GaN on SiC products spanning plastic, ceramic and pallet options for pulsed and continuous wave applications. MACOM is thus firmly established as a leader across all GaN variants and end-market requirements.

In terms of supply chain, MACOM's recently announced collaboration with IQE will drive capacity and economies of scale for mass market 8" silicon cost structures.

In this manner, MACOM is taking a leadership role in breaking the final technology and commercialization barriers to mainstream GaN adoption. In doing so, we're building a sustainable technology and supply chain model which will be viable for decades to come.

John Croteau

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President and CEO
MACOM

Learn more at www.macom.com/gan